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JOURNAL OF THE
AERONAUTICAL SCIENCES

Volume 4 AUGUST, 1937 Number 10

Icing Measurements on Mount Washington

S. PAGLIUCA, *Blue Hill Observatory, Harvard University*

Presented at the Meteorology Session, Fifth Annual Meeting, I. Ae. S. January 28, 1937

THIS paper discusses experimental methods used on Mount Washington for the measurement of rime deposition and their possible application to the study of icing on aircraft. Investigations of rime deposition on Mount Washington were started last year for the purpose of determining the water contribution of rime to runoff. It soon became apparent that conditions were favorable for carrying out tests of icing of aircraft under natural conditions.

Rime-forming fogs are very frequent on Mount Washington. During the year 1933, fog was recorded on 318 days, or 87 percent of all days, and on 2600 hours, or 52.5 percent of all hours. Even during the summer months there are occasional rime and sleet storms. Fall and spring are the seasons when the heaviest deposits occur because moderately cold, yet sufficiently moist, air masses are more frequent then. The wind velocity has been found to average 40 m.p.h. for the year, with frequent prolonged spells of 100 m.p.h. and extremes of 200 m.p.h. or over, have been recorded at times. The lowest temperature observed since the establishment of the present observatory in 1932 is −47°F. Therefore a wide range of conditions is experienced.

Most of the data concerning icing on aircraft have been contributed by pilots, but naturally they should be more concerned with safety than with experimenting with rapidly forming ice. The chief advantages of experimenting on Mount Washington are that tests can be carried on continuously over long periods, and the meteorological elements characterizing the air mass and responsible for the particular ice formation can be accurately obtained during the test.

Refrigerated wind tunnels in some respects may offer a better method, since it is possible to control the temperature and moisture content of the air, but an adiabatic atmosphere, *i.e.*, one with a vertical lapse-rate of the temperature and humidity of the air stream as in nature cannot be readily reproduced in a tunnel. Lacey[1] has shown lapse-rate to be a very important factor in icing conditions. Air mass modifications due to forced ascent over the mountain top generally can be accounted for with a fair degree of accuracy. While means for preventing or eliminating ice deposits on aircraft are being steadily improved, a better understanding of the physics and meteorology of ice formation—especially the establishment of definite relationships between the occurrence of various types of ice and the meteorological elements determining their formation—is essential.

Coordination of efforts of various investigators here and abroad has been somewhat impaired by the inadequacy of present terminology on rime, frost, and ice. Definitions of the different forms of ice used by aviators and meteorologists are still superficial and confusing. The International Meteorological Committee adopts for general purposes the classification: glazed frost, (soft and hard) rime, and hoarfrost. Airway meteorologists in the United States distinguish "rime ice" and "clear ice," often with some subdivision ("smooth" or "rough," etc.). The International Climatological Commission has entrusted Dr. Bergeron with the preparation of a memorandum

[1] J. K. Lacey, *A Study of Meteorological Conditions During the Formation of Ice on Airplanes*, M.S. Thesis, M.I.T., 1936.

FIG. 1. Experimental model of airfoil, Mount Washington, N. H. (1915 m.). Observatory building to the right, with electrically heated anemometer on the roof.

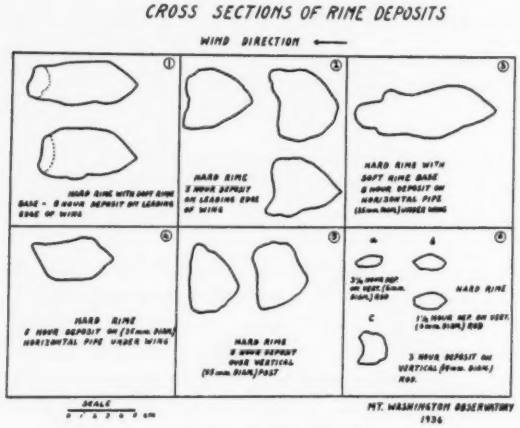
CROSS SECTIONS OF RIME DEPOSITS
WIND DIRECTION
HARD RIME WITH SOFT RIME BASE - 8 HOUR DEPOSIT ON LEADING EDGE OF WING
HARD RIME 3 HOUR DEPOSIT ON LEADING EDGE OF WING
HARD RIME WITH SOFT RIME BASE 8 HOUR DEPOSIT ON HORIZONTAL PIPE
HARD RIME 8 HOUR DEPOSIT ON HORIZONTAL PIPE UNDER WING
HARD RIME 8 HOUR DEPOSIT OVER VERTICAL POST
HARD RIME
3 HOUR DEPOSIT ON VERTICAL ROD
SCALE
MT. WASHINGTON OBSERVATORY 1936

FIG. 2. (See Table 1.)

with new definitions and symbols for some of the hydrometeors, but probably some more detailed classification such as Seligman's will be much better for aviation purposes.[2]

[2] Bulletin of the American Meteorological Society, pp. 5–10, January, 1937.

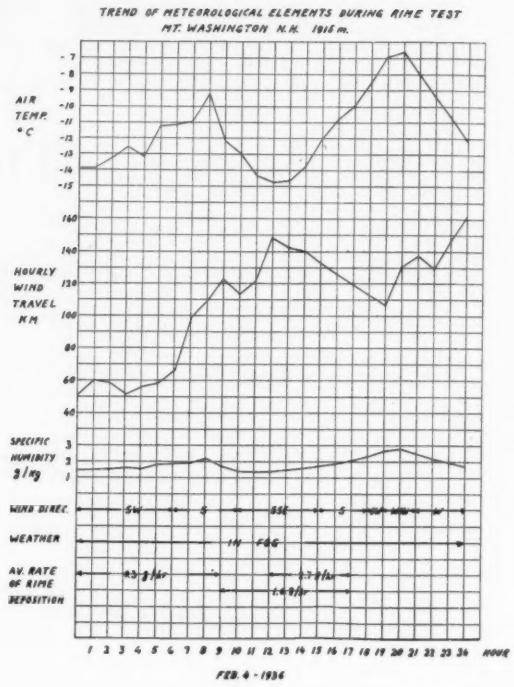

FIG. 3.

On February 4, 1936, the author, while on a visit to the Mount Washington Observatory, carried on a series of tests to obtain rates ofd eposition and densities of rime on a model of an airplane wing. The model, obtained through the courtesy of the Curtiss-Wright Corporation, consisted of a section of a metal airfoil, with a 91 cm. chord and 10 cm. maximum thickness, installed 5 meters above the ground, (Fig. 1). It was free to adjust itself to the wind so that the leading edge was generally normal to and pointing into the wind.

The method used to determine densities consisted in "scraping off" sections of rime from the wing, cut-

TABLE 1. Results of Rime Deposition

Case	Figure[1]	Time[2]	No. of Hours	Average Length Deposit Cm.	Average Rate of Deposit 1 Cm. Model Cm./Hr.	Total Weight Melted Per Cm. Sample Gr.	Average Rate Deposit Gr./Hr.	Average Density Gr./Cm.	Total Wind Travel Km.	Hourly Wind Travel Km.
1	..	**12:00–9:00**	9.00	4.5	0.50	2.66	0.295	0.270	679	76
2	6a	12:00–**3:15**	3.25	2.0	0.60	1.10	0.338	0.875	439	135
3	..	**2:00–3:15**	1.25	0.5	0.40	...	...	...	158	126
4	6b	**3:15–4:45**	1.50	2.5	1.70	...	...	...	167	111
5	6c	**2:00–5:00**	3.00	1.8	0.60	3.10	1.033	0.814	354	117
6	1	9:00–**5:00**	8.00	8.5	1.06	1.99	0.248	0.901	1016	127
7	2	12:00–**5:00**	5.00	4.0	0.90	13.40	2.680	0.785	636	127
8	3	9:00–**5:00**	8.00	8.5	1.06	13.00	1.625	0.469	1016	127
9	4	12:00–**5:00**	5.00	5.7	1.14	13.85	2.770	...	636	127
10	5	12:00–**5:00**	5.00	3.7	0.74	13.50	2.700	0.961	636	127

[1] This column refers to the number of the cross section in Fig. 2. [2] Bold face figures indicate p.m., light face a.m.

FIG. 4. The Mount Washington Observatory building heavily coated with rime. Note 3 ft. rime deposit on anemometer mast and 5 in. diameter accumulation on radio antenna.

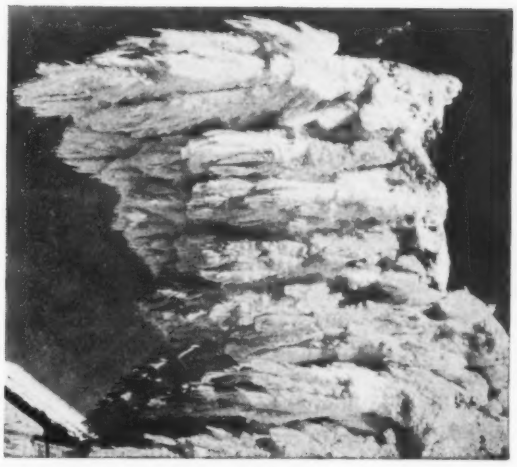

FIG. 5. Rime from a single storm, October, 1932, on Pyrheliometer post.

ting a reasonably uniform sample of about 10 cm. in length, drawing one or more cross sections directly on cross section mm. paper, computing the average cross-sectional area of the sample, and its approximate volume, (Fig. 2). The sample was then allowed to melt, its water equivalent weighed, and the weight of water per unit volume of rime computed.

The synoptic situation during the day of February 4, 1936, was characterized by the presence of a major disturbance over the region of the Great Lakes, and a wave disturbance off the North Atlantic coast. The latter was responsible for an active inflow of Polar Maritime air in the Mount Washington region during the day. It is probable that the warm sector of the Great Lakes cyclone barely reached the Mount Washington region, although no appreciable northward flow of real tropical air was actually observed.

The trends of the various meteorological elements on Mount Washington at this time are shown in Fig. 3. In addition to the wing model, two vertical rods were exposed. Rod No. 1 was 6 mm. in diameter and 24 cm. high, set on a table about 1 meter from the ground. Rod No. 2 was 19 mm. in diameter and 23 cm. high, set on a rain-gage box about one meter from the ground.

Table 1 gives a summary of the various tests. In the last column mention is made of the object on which the sample of rime was collected. It is evident from columns 8 and 9 of the table that the rate of deposit as well as the average density change considerably with the exposure and shape of the object on which the deposit forms. Inasmuch as the specific humidity at a given instant is practically constant near the various collectors, it follows that the wind velocity is the chief factor affecting the rate of deposition and the

Test on Mt. Washington, N. H. (1915 m.)

Air Temperature °C			Specific Humidity Gr./Kg.			
Maximum	Minimum	Average	Maximum	Minimum	Average	
−9.4	−13.9	−11.7	2.16	1.43	1.79	Soft rime on leading edge of wing.
−11.7	−13.9	−12.8	1.85	1.47	1.64	Hard rime on rod No. 1.
−12.2	−13.3	−12.8	1.75	1.55	1.65	Hard rime on rod No. 2.
−11.1	−12.2	−11.7	2.00	1.75	1.87	Hard rime on rod No. 1.
−10.0	−13.3	−11.7	2.06	1.55	1.80	Hard rime on rod No. 2.
−10.0	−13.9	−11.9	2.06	1.32	1.69	Hard rime with base of soft rime on leading edge of wing.
−10.0	−15.0	−12.5	2.06	1.47	1.76	Hard rime on leading edge of wing.
−10.0	−15.0	−12.5	2.06	1.32	1.69	Hard rime with base of soft rime on horizontal pipe under wing.
−10.0	−15.0	−12.5	2.06	1.32	1.69	Hard rime on horizontal pipe under wing.
−10.0	−15.0	−12.5	2.06	1.32	1.69	Hard rime on vertical post.

density over various objects or different parts of the same object in a given length of time, provided no appreciable change in air-mass properties has taken place. The wind velocities given in the table were obtained from the station's electrically-heated anemometer located 3 meters above the top of the observatory building and 7.7 meters above the ground, about 15 meters away from the location of the rime collectors; therefore they can be used only for rough comparison purposes.

An idea of the order of magnitude of the phenomenon can be obtained by examining case No. 6 as an example. Over a period of 8 hrs. the average rate of deposition over the leading edge of the wing was 1.06 cm. per hr. with an average wind velocity at the anemometer of 35 meters per sec. and an average specific humidity of 1.7 g. per kg., the density of the hard rime with a 15–20 mm. base of soft rime being 0.9 g/cm.[3]

In general the densities of hard rime are similar to those of ordinary ice, but soft rime densities are considerably lower as in case No. 8, which is a combination of soft and hard rime, and case No. 1, which is soft rime. Some apparent discrepancies in the density values are probably the result of inaccuracies inherent to the method used in determining them.

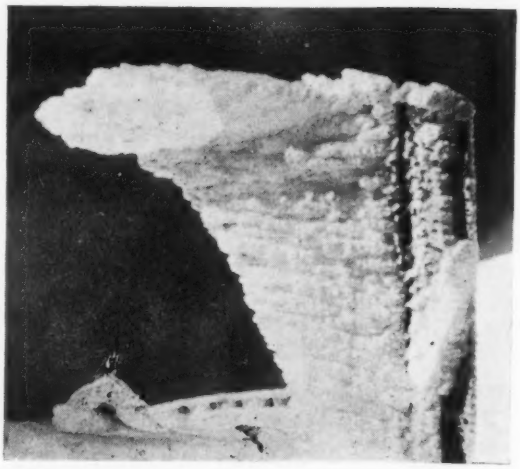

FIG. 6. Rime formation on a wooden post, showing the length increasing with height above the ground, a direct result of increasing velocity with height.

Due to an insufficient number of measurements no definite conclusion can be derived from the above, but the method, perhaps improved, can be made to yield useful results.

Book Review

Aerodynamics, by DR. N. A. V. PIERCY; D. Van Nostrand Company, Inc., New York, 1937; 423 pages, ill., $9.00.

While a number of books have appeared in English on aerodynamics applied to design, with appropriate collection of data, we seem to remember but very few texts devoted to the theory of aerodynamics as distinguished from its application. In view of this situation, Dr. Piercy's book is highly welcome since it contains within the covers of one book all those portions of the theory of aerodynamics, likely to be needed by any student, except the highly advanced specialist, and all the theoretical aerodynamics which the busy practicing engineer is likely to make use of.

While there is always the annoying difficulty that British absolute coefficients are one-half the numerical value of the American coefficients, there is in other respects no divergence from American terminology or methods of presentation. This is not astonishing after all, for while the science has advanced independently in England, Germany, the United States, and other countries, the internationalization of ideas has been very rapid.

A rather short treatment of the atmosphere and aerostatics is followed by a second chapter which is a splendid presentation of the elements of stream flow, compressible and non-compressible flow, dimensional similarity, and the Reynolds Number. In the chapter on Wind Tunnel Experiment, scale effects and the elements of such experimentation are well presented. Correlation between model test and full scale is carried a little further in American practice than would appear to be the case in England. Chapter IV, Aircraft in Steady Flight, is a concise elementary treatment of the subject. It is, however, with Chapter V, Fundamentals of the Irrotational Flow that the high value of this book asserts itself. Thus in Fundamentals of Irrotational Flow, we have the indispensable notions of stream functions and potential functions in a form which can be readily accepted by the student or busy engineer. In Chapter VI, on Two-Dimensional Aerofoils, the theory of Joukowski and other airfoils, conformal transformation and all the necessary vortex theories are dealt with in the clearest and simplest manner. The chapter on Wing Theory gives the necessary elements for understanding the theory of tapered wings, induced drag, various cases of tunnel wall interference, and so forth. Chapter IX dealing with Viscous Flow and Skin Drag is a compact and readily intelligible presentation of viscous flow and the elements of turbulence theory, which is so puzzling on a first reading. Air screws and autogiros are then well but briefly treated. Performance and efficiency in Chapter XI contains the essential elements. The last chapter, Safety in Flight, is a fine summary of the theory of dynamic stability, longitudinal and lateral, in a form entirely suitable for a first reading and for subsequent reference.

The illustrations, formulae, and derivations are presented in a careful and scholarly manner and it would be difficult to find a single flaw in presentation, formulae, or terminology within the four hundred odd pages of the book.

From a student's point of view, nothing would so well accompany and supplement a reading of say Diehl's Engineering Aerodynamics, as assiduous study of Piercy's Aerodynamics.

ALEXANDER KLEMIN
New York University

The Heat-Transfer Processes in Air-Cooled Engines

BENJAMIN PINKEL, *National Advisory Committee for Aeronautics*

Presented at the Engines and Fuels Session, Fifth Annual Meeting, I. Ae. S.
January 28, 1937

ENGINE-CYLINDER temperatures are important factors in limiting the power of air-cooled engines. An insight into the manner in which cylinder temperatures vary is obtained from a study of the heating of the cylinder walls by the engine gases and the cooling of the cylinder walls by the passage of heat through the fins to the fin surfaces where the heat is carried off by the cooling air stream. For any set of engine and cooling conditions the cylinder temperatures attain an equilibrium at which the rate of heating of the cylinder is equal to the rate of cooling.

In the subject paper, from a consideration of heat-transfer theory, expressions have been obtained for the rate of heat transfer from the engine gases to the cylinder walls and from the cylinder walls to the cooling air. These expressions contain several empirical constants, values for which were obtained from test data for a Pratt & Whitney 1340-H cylinder. The test data were obtained by the N.A.C.A. at its engine laboratories at Langley Field, Va. From these expressions, equations are obtained for the average cylinder head and barrel temperatures as functions of the fundamental engine and cooling variables. Although the maximum head and barrel temperatures are the limiting factors, a good approximation to the variation in the maximum temperatures may be obtained from the variation in the respective average temperatures.

The average head and barrel temperatures calculated from the equations were found to check experimental values with a good degree of accuracy. Although the empirical constants apply to a particular engine and cooling arrangement, the equations provide a better understanding of the cooling of air-cooled engines in general. The empirical constants associated with the heat transfer from the engine gases to the cylinder appear at present to apply to other engines of a similar type.

Heat Transfer by Forced Convection

In both the heating and cooling of the cylinder walls the transfer of heat between a moving gas and a surface plays an important part. It is known[1] that the heat-transfer coefficient q for forced convection is a function of the gas velocity, density, conductivity, viscosity, and specific heat as well as of the dimensions of the bodies involved. It is evident that in any expression for q the foregoing factors must so combine as to give the physical dimensions of q. A general expression from which may be obtained any desired combination of the factors having the dimensions of q is given by

$$q = C_p \rho V f\left(\frac{\rho V s}{\mu}, \frac{\mu C_p}{K}, r_1, r_2, r_3, \ldots\right) \qquad (1)$$

where q is the rate of heat transfer per unit surface area per unit temperature difference between the surface and the gas; V is the gas velocity; ρ is the gas density; μ is the gas viscosity; C_p is the gas specific heat at constant pressure; s is a characteristic length of the body; and r_1, r_2, etc., are the ratios of the other important body dimensions to s.

The foregoing relation, which has been set up by a consideration of only the dimensions of the quantities involved, has been found to hold for the cooling of flat plates, pipes, and fin and cylinder surfaces by moving gases and liquids. Its usefulness is evident since by grouping the many variables into factors such as $\rho Vs/\mu$ (the Reynolds Number) and $C_p\mu/K$ (the Prandtl number) the testing required to establish the equation for q is reduced to a minimum.

The convection of heat from a surface by a moving gas is brought about by the same mechanism that gives rise to surface friction. It may be recalled that the friction between two adjacent fluid layers moving at different velocities is caused by an interchange of fluid particles between the layers resulting from the random molecular movement associated with fluid temperature for laminar flow and, in addition, from small swirls for turbulent flow. These same interlayer movements interchange particles in the warmer layers with particles in the colder layers and result in a diffusion of heat in the direction of the colder layers. With the transition from laminar to turbulent flow a large increase in heat transfer naturally occurs. In some special cases a direct relation exists between the surface friction and the surface heat-transfer coefficient.[2]

The values of the viscosity, conductivity, and specific heat in Eq. (1) vary with temperature; however,

[1] William H. McAdams, *Heat Transmission*, McGraw-Hill Book Company, Inc., 1933.

[2] Franz Elias, *The Transference of Heat from a Hot Plate to an Air Stream*, N.A.C.A. Tech. Memo. 614, 1931.

Luigi Crocco, *Transmission of Heat from a Flat Plate to a Fluid Flowing at a High Velocity*, N.A.C.A. Tech. Memo. 690, 1932.

Stanton, Phil. Trans. Roy. Soc., A190, 67 (London), 1897.

the Prandtl number for gases remains practically constant.[3]

Heat-transfer tests have shown that, in general, q is proportional to $(\rho V)^n$ where the value of n depends on the body cooled and on the range of Reynolds Number involved. For example, in the cooling of a flat plate $n = 0.5$ when a laminar boundary layer exists and 0.8 for a turbulent boundary layer. It is clear that to obtain q proportional to $(\rho V)^n$ the function of the Reynolds Number must be $\left(\frac{\rho Vs}{\mu}\right)^{n-1}$ The equation for q for a gas may then be written

$$q = C_p \rho V \left(\frac{\rho Vs}{\mu}\right)^{n-1} f(r_1, r_2, r_3, \ldots) \qquad (2)$$

Heat Transfer from Cylinder Gases to Cylinder Wall

The transfer of heat from the engine gases to the cylinder walls takes place mainly by radiation and convection. Nusselt[4] concludes from a study of engine and combustion-bomb data that radiation accounts for only 10 percent of the total heat transferred. As aircraft engines operate at much higher speeds than the engines studied by Nusselt, it may be expected that in the present case radiation is even less important in comparison with convection.

Several attempts have been made to obtain the variation of the instantaneous heat-transfer coefficient during the engine cycle.[4,5] The difficulty of the problem is seen from the fact that, in addition to the continual variation in V, ρ, μ, C_p, and K during the cycle (see Eq. (1)), account must also be taken of the varying gas turbulence. The present paper deals with the simpler problem of obtaining the average rate of heat transfer over the entire cycle.

The various gas movements that take part in the transfer of heat are the flow of the gases through the intake and exhaust ports, the sweeping of the gases over the cylinder barrel and head surfaces produced by the piston movement, and the turbulence which may be set up in the gases. A source of turbulence is the high gas velocity through the intake port, which reduces to a swirl when the gas enters the cylinder. During combustion there is evidence of the existence within the charge of a field of small swirls. Marvin and his associates[6] suggested that these swirls are the mechanism whereby the flame is propagated in the cylinder to explain the fact that the rate of flame propagation increased with engine speed. It is evident that this mechanism also would transfer heat and, although little is known about it, may be one of the most important contributing factors.

Possible sources of this small-grain turbulence may be the breaking down of the swirl introduced during the suction stroke or of an unstable flow condition set up by the rapid compression of the engine gases. Finally additional gas turbulence may result from the friction of the gases in flowing over the cylinder surfaces and from the combustion of the charge.

In all the components of this complicated gas movement the characteristic is evident that the linear and rotational velocities are proportional or nearly proportional to the engine speed. The assumption will therefore be made that the velocity V in Eq. (2) can be replaced by a product of the engine speed and a function of the crank angle. It will also be assumed that for a given engine the function of crank angle is independent of the engine-operating conditions as the piston goes through the same motion only faster or slower depending upon the engine speed.

The density ρ is obviously equal to the product of the weight of gases in the cylinder and a function of crank angle. The quantities s and r_1, r_2, etc., are either constants or functions of the crank angle for a given engine. It will be shown later that the value of C_p/μ^{n-1} corresponding to an average effective gas tempera ture for the gas cycle does not appreciably vary for the range encountered in ordinary operation. Although C_p/μ^{n-1} varies during any given cycle it will be assumed that its effect is approximately the same for all cycles.

Introducing the foregoing assumptions in Eq. (2) the instantaneous heat-transfer coefficient of the gas is

$$q_a = W_T^n f(\theta) \qquad (3)$$

where W_T is the product of the weight of gases in the cylinder and the number of cycles per minute and $f(\theta)$ combines the variation with crank angle of all the factors in Eq. (2) and also the constants of the equation. In accordance with the preceding discussion $f(\theta)$ is independent of the engine-operating conditions. The quantity W_T may be looked upon as the weight of gas flowing through the engine per minute adjusted to include the weight of residuals.

Over the entire cycle the average of the rate of heat transfer to the cylinder head is obviously given by

$$H = \frac{a_1}{4\pi} \int_0^{4\pi} q_a (T - T_h)\, d\theta$$

or

$$H = \frac{a_1 W_T^n}{4\pi} \int_0^{4\pi} f(\theta) [T - T_h]\, d\theta \qquad (4)$$

where H is the heat transferred per unit time, a_1 is the

[3] Leonard B. Loeb, *Kinetic Theory of Gases*, McGraw-Hill Book Company, Inc., 1927.

[4] Wilhelm Nusselt, *Transfer of Heat in the Internal Combustion Engine*, Diesel Maschinen, Verlag des Vereines Deutscher Ingenieure, 1923.

[5] August Herzfeld, *Der Warmeubergang und die thermodynamische Berechnung der Leistung bei Verpuffungsmaschinen insbesondere bei Kraftfahrzeug-Motoren*, Julius Springer (Berlin), 1925.

[6] Charles F. Marvin, et al, *Further Studies of Flame Movement and Pressure Development in an Engine Cylinder*, N.A.C.A. Tech. Report 556, 1936.

internal area of the head, T_h is the average temperature over the head surface, and T is the instantaneous gas temperature. It should be noted that q_g and T are average values over the cylinder head.

Defining B as follows

$$B = \frac{1}{4\pi}\int_0^{4\pi} f(\theta)\, d\theta$$

it may be seen from Eq. (3) that BW_T^n is the mean heat-transfer coefficient over the complete cycle. The temperature obtained by averaging the product of the instantaneous gas temperature by the ratio of the instantaneous to the mean heat-transfer coefficient over the complete cycle will be referred to as the "effective" gas temperature. The effective gas temperature by definition is given by the following expression

$$T_g = \frac{1}{4\pi B}\int_0^{4\pi} T\, f(\theta)\, d\theta$$

Eq. (4) may now be written

$$H = Ba_1\, W_T^n\, (T_g - T_h) \qquad (5)$$

Eq. (5) thus gives a simple expression for the rate of heat transfer to the head.

The i.hp. I of an engine is proportional to the weight of mixture inducted into the engine per unit time for a constant air-fuel ratio. In the range to the rich side of the theoretically correct mixture I varies only slightly with air-fuel ratio. The weight of mixture differs from the total weight in the engine by the weight of residuals. However, the difference is sufficiently small so that an equation similar to Eq. (5) but involving I instead of W_T may be written

$$H = \overline{B}a_1\, I^{n'}\, (T_g - T_h) \qquad (6)$$

This equation is applicable in the range of air-fuel ratios below 14.7. It does not predict the variation in heating that occurs when the weight of residuals is varied, as in operating at various exhaust pressures.

The constants B, $\overline{B}$, n, and n' and the effective gas temperatures T_g will be obtained from engine tests. It is necessary to isolate the variables upon which the quantity T_g depends. From a consideration of the equation for the temperatures developed in an engine cycle as a function of the rate of combustion of the charge and from combustion curves obtained from the analysis of indicator cards, the conclusion was reached that, as a good first approximation, T_g is independent of the weight of gases in the cylinder and of the engine speed and is a function of the air-fuel ratio, the spark timing, the compression ratio, and the manifold air temperature. It can be obtained by an equation of the following form

$$T_g = CT_m + f(A, S, R) \qquad (7)$$

where C is a constant; T_m is the intake manifold temperature; A is the air-fuel ratio; S is the spark timing; and R is the compression ratio.

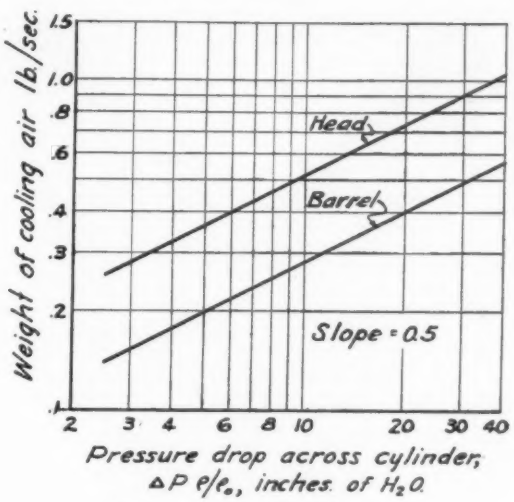

FIG. 1. Calibration of air duct.

The equations for the barrel will be assumed to take the same form as Eqs. (5), (6), and (7). The values of the constants and of T_g will, however, be different and T_h will be replaced by T_b, the average cylinder barrel temperature. Part of the heat is transmitted to the barrel by the piston. The heating of the piston by the engine gases is similar in process to the heating of the cylinder head. In the conduction of the heat from the piston to the barrel, however, additional factors such as the resistance to the flow of heat through the piston, piston rings, and oil films make their appearance. The cooling produced by the flow of oil and heating due to friction also affect the barrel temperatures. Some of these factors are taken care of by the empirical constants in the equations. The final justification for the foregoing assumption is, however, that good results are obtained by the use of the equations. Some variation in the value of the constants B and $\overline{B}$ for the barrel may be expected as the condition of the piston, piston rings, and cylinder change and also as the quantity of lubricant circulated changes.

EXPERIMENTAL RESULTS

The tests on the Pratt & Whitney 1340-H cylinder were made on a single-cylinder dynamometer test stand. The cylinder was enclosed in a duct to which cooling air was supplied by a blower. Electrical heating units in the air duct provided a means for varying the cooling-air temperature. Separate passages were provided for the air that cooled the head and the barrel. A calibration made of the weight of air flowing through each passage as a function of the pressure drop across the duct is shown in Fig. 1. The quantity ρ/ρ_0 is the ratio of the average density of the air flowing around the cylinder to a density corresponding to a temperature of 70°F. at 29.92 in. Hg. Thermocouples

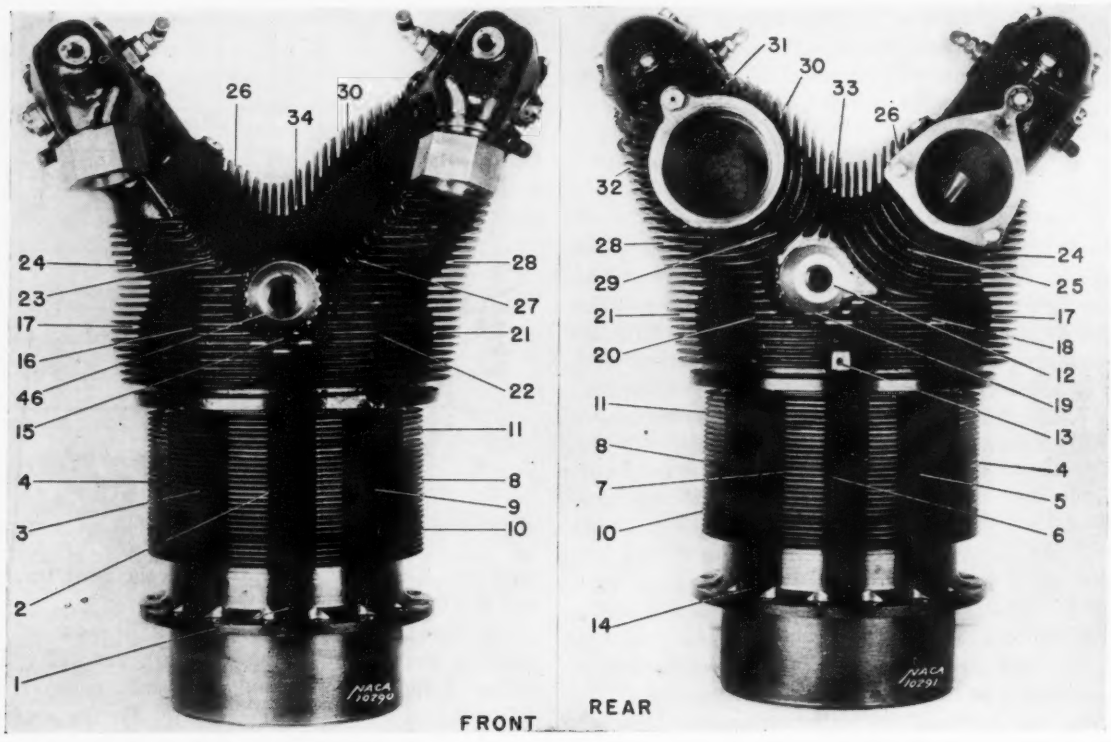

FIG. 2. Location of thermocouples on cylinder.

located in each of the air streams ahead of and behind the cylinder measured the rise in cooling-air temperature. The heat dissipated from the head and barrel was calculated from the weight of air passed and from the temperature rise in each passage. The average cylinder head and barrel temperatures were obtained by averaging the readings of 22 thermocouples on the head and 10 thermocouples on the barrel. The locations of these thermocouples are shown in Fig. 2. The air-fuel ratio was measured by a calibrated Cambridge meter. The engine brake mean effective pressure, rotational speed, rate of fuel flow, and inlet manifold temperature were measured by the standard test-stand equipment.

An air-fuel ratio of 12.3 was chosen as a standard at which all tests were to be made except those to determine the effect of air-fuel ratio on T_g. The value of T_g at the standard air-fuel ratio was obtained in the following manner. It will be noted in Eqs. (5) and (6) that H is zero when T_h equals T_g. Tests were made in which all engine conditions were held constant and the cylinder temperature was varied by varying the cooling-air temperature. The heat quantities dissipated from the head and barrel were plotted against the average head and barrel temperatures. The test points were fitted by straight lines which upon extrapolation to zero heat output gave the values of T_g for the head and barrel. Because of the large temperature range through which the extrapolation must be made a single determination is not very accurate. The average of a large number of such determinations for various test conditions gave values for T_g of 1150°F. and 600°F. for the head and barrel, respectively.

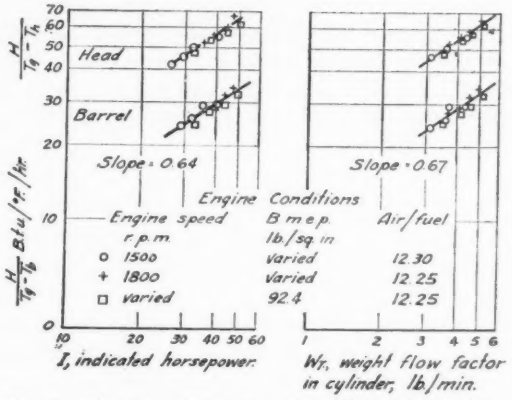

FIG. 3. Variation of heat-transfer coefficient from cylinder gas to cylinder head and barrel with I and W_T.

Making use of these values of T_g the quantities $a_1\overline{B}\,I^{n'}$ and $a_1 B W_T^{n}$ which are equal to $H/(T_g - T_h)$ (see Eqs. (5) and (6)) were calculated from tests in which the brake mean effective pressure and engine speed were varied. Fig. 3 shows $H/(T_g - T_h)$ plotted against I and W_T on logarithmic coordinates. It will be noted that the points fell on the same curve irrespective of whether the engine speed or brake mean effective pressure was varied. The following equations

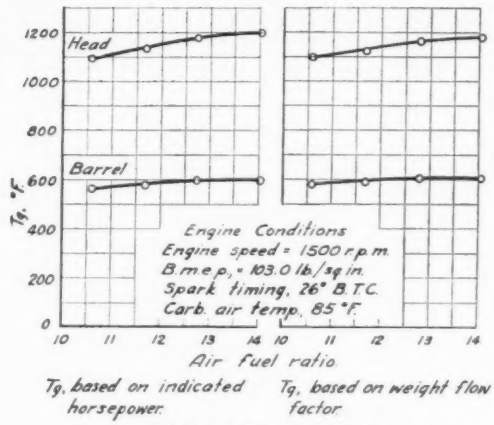

FIG. 4. Variation of T_g with air-fuel ratio.

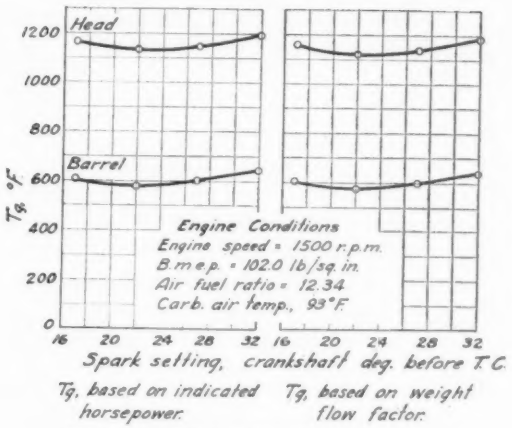

FIG. 5. Variation of T_g with spark setting.

for the heat transferred to the head and barrel were obtained from these curves,

$$\left.\begin{array}{ll}\text{Head} & H = 5.22\, I^{0.64}\,(T_g - T_h)\\ \text{Barrel} & H = 2.74\, I^{0.64}\,(T_g - T_b)\end{array}\right\} \qquad (8a)$$

$$\left.\begin{array}{ll}\text{Head} & H = 20.7\, W_T{}^{0.67}\,(T_g - T_h)\\ \text{Barrel} & H = 10.8\, W_T{}^{0.67}\,(T_g - T_b)\end{array}\right\} \qquad (8b)$$

where H is in B.t.u./hr., W_T in lb./min. and T_g in °F.

The internal area a_1 for the head is 76.8 sq. in. and for the barrel is 84.2 sq. in. Using these areas the values of $\overline{B}$ and B calculated from the coefficients in Eqs. (8) are

	$\overline{B}$	B
Head	0.0680	0.270
Barrel	.0325	.128

The area a_1 of the head included, besides the internal area of the head exposed directly to the gases, the area of the liner down to the end of the head and the area of the valves. The area of the exhaust passage outside the combustion chamber was not considered and was compensated for to some extent by including the valve areas. The barrel area was taken as the internal area of the liner from the end of the head to the bottom of the lowest piston ring with the piston at bottom center.

The heat transferred by radiation is included in H in plotting Fig. 3 and in obtaining the above constants. Some scattering of the points in Fig. 3 would be expected as the heat transfer by radiation follows a different law than that by convection. No very great scattering is noted indicating either that the heat transfer by radiation is small or that it follows roughly the same variation as the heat transfer by convection for the range shown.

The values of T_g calculated by means of Eqs. (8) from tests in which the air-fuel ratio, the spark timing, and the inlet manifold temperature were varied are shown in Figs. 4, 5, and 6, respectively. The values of T_g obtained from the two sets of equations are approximately the same. In the range of lean mixtures, Eq. (8a) would be expected to become inaccurate.

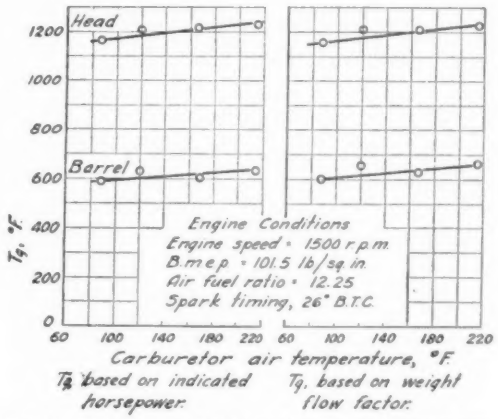

FIG. 6. Variation of T_g with carburetor-air temperature.

Fig. 4 shows that for the rich-mixture range T_g decreases slightly as the mixture becomes richer. It may be noticed that T_g remains practically constant over the range of spark settings normally used and increases for advanced and retarded spark settings. In the present case, the effect of manifold temperature was to increase T_g by 0.58°F. for every degree increase in manifold temperature.

With reference to the variation of the value of C_p/μ^{n-1} corresponding to T_g previously mentioned it is now evident that T_g for the head varies from 1150 to 1250°F. and for the same range C_p/μ^{n-1} only changes by 1.6 percent.

It remains to be seen how much the values of B, $\overline{B}$, n, and n' vary between cylinders. Some variation may be expected with variation in cylinder diameter and bore-to-stroke ratio. The value of the constants should also be affected if the engine is designed to provide a large amount of turbulence. In tests on one smaller cylinder, values for the foregoing constants were obtained very similar to those for the Pratt & Whitney 1340-H cylinder.

Transfer of Heat to Cooling Air

The rate (B.t.u. per hour) at which heat is transferred from the cylinder head to the cooling air is given by

$$H = a_0\, U(T_h - T_a) \tag{9}$$

where a_0 is the area of the cylinder head covered by fins (142 sq. in. for the Pratt & Whitney 1340-H cylinder); U is the overall heat transfer coefficient for the head in B.t.u. per hour per square inch of head area per °F. difference between the average head temperature and the cooling air; and T_a is the temperature of the cooling air in °F.

A similar equation may be written for the barrel. The area of the barrel covered by fins for the Pratt & Whitney 1340-H cylinder is 68.7 sq. in.

By equating H in Eqs. (8) and (9) the following expressions are obtained for the average head and barrel temperatures

$$\left.\begin{aligned} T_h - T_a &= \frac{T_g - T_a}{\frac{a_0 U}{5.22\, I^{0.64}} + 1} \\ T_b - T_a &= \frac{T_g - T_a}{\frac{a_0 U}{2.74\, I^{0.64}} + 1} \\ T_h - T_a &= \frac{T_g - T_a}{\frac{a_0 U}{20.7\, W_T^{0.67}} + 1} \\ T_b - T_a &= \frac{T_g - T_a}{\frac{a_0 U}{10.8\, W^{0.67}} + 1} \end{aligned}\right\} \tag{10}$$

The relation between the indicated horsepower I and the heat-transfer coefficient U which must be provided to obtain various average head and barrel temperatures are shown in Table 1.

The values in the table were obtained from Eqs. (10) for $T_a = 70$°F. and for $T_g = 1150$°F. for the head and 600°F. for the barrel. It is evident from Eqs. (10) that for an increase in U from U_1 to U_2 the indicated horsepower may be increased in the ratio $I_2/I_1 = (U_2/U_1)^{1.56}$ without increasing the average cylinder temperatures.

The values of U depend on the fins, baffling, and air flow provided for cooling. It may be shown that, for the range of air speeds normally encountered, in engine cooling U may be expressed as

$$U = A(\rho V)^m$$

where V is the cooling-air velocity, ρ the cooling-air density, and A and m are constants which apply for a particular fin design, baffling, type of cooling, and range of mass flow ρV.

Table 1

Head		Barrel	
T_h	$U/I^{0.64}$	T_b	$U/I^{0.64}$
°F.		°F.	
200	0.269	150	0.428
250	.184	200	.234
300	.136	250	.148
350	.105	300	.099
400	.084	350	.068

As the values of ρV for the cylinder-head fins are proportional to W_h, the weight of air flowing around the head per unit of time, the U for the head may be written

$$U = A_1(W_h)^m$$

The U for the barrel may be written as a similar function of the weight of air flowing around the barrel per unit of time W_b.

The following brief discussion of the cooling of finned cylinders is included to give a better insight into the limitations of the foregoing expressions, the factors on which U depends and to mention the data that are now available for calculating U.

As the transfer of heat from the cylinder to the cooling air consists of the conduction of heat through the fins to the fin surfaces and of the convection of heat from the fin surfaces to the cooling air, it is evident that U can be written as a function of the dimensions, the thermal conductivity, and the surface heat-transfer coefficient q of the fins. Such equations may be obtained from the theoretical analysis of the conduction of heat through fins of various shapes made by Harper and Brown[7] and by Schmidt.[8] The following convenient equation for U has been found[9] to hold with a fair degree of accuracy for cylinders having fins of rectangular or tapered profile,

$$U = \frac{q}{s + t}\left[\frac{2}{a}\frac{R_a}{R_b}\tanh aw' + s_b\right] \tag{11}$$

where

$$a = \sqrt{\frac{2q}{Kt}}$$

and K, Thermal conductivity of fins, B.t.u./hr./sq. in./°F. through one inch.

s, Average air space between adjacent fins, inches.

---

[7] D. R. Harper 3d and W. B. Brown, *Mathematical Equations for Heat Conduction in the Fins of Air-Cooled Engines*, N.A.C.A. Technical Report 158, 1923.

[8] E. Schmidt, *Die Wärmeübertragung durch Rippen*, V.D.I., June 26, 1926, and July 10, 1926.

[9] Arnold E. Biermann and Benjamin Pinkel, *Heat Transfer from Finned Metal Cylinders in an Air Stream*, N.A.C.A. Technical Report 488, 1934.

s_b, Cylinder wall space exposed between adjacent fins, inches.
t, Average thickness of fin, inches.
$w' = w + t/2$, where w is width of fin, inches.
R_b, Radius to base of fin, inches.
$R_a = R_b + w/2$, average radius of fin, inches.
q, Average surface heat-transfer coefficient of fins defined as B.t.u.'s transferred per hour per square inch of fin surface per °F. average temperature difference between the fin surface and the cooling air.

Experimental values for q have been obtained[9,10] for finned cylinders in a free air stream and in an air duct[11] and, together with Eq. (11), provide a means for calculating U for the cylinder barrel for the equivalent cooling set-up. No values of q have been obtained as yet for a set-up equivalent to a cowled engine. No experimental values have been obtained for q for cylinder heads or for finned bodies similar in shape to cylinder heads.

Eq. (2) also applies to the surface heat-transfer coefficients of fins in which V is a characteristic velocity, such as the average velocity between the fins, ρ is the average air density, s is the average air space between adjacent fins and r_1 is the ratio of s to the cylinder diameter. The other fin dimensions for the usual fin designs are of minor importance in determining q. The baffling of the cylinder and the turbulence of the air also affect the value of q.

Reference to Eqs. (2) and (11) shows that for a given fin design U varies only with ρV. The quantity C_p/μ^{1-n} has only a small effect and may be considered constant as in the case of q_g. For the range of variation of ρV covered in the cooling of a given engine, U may be written

$$U = A(\rho V)^m$$

as previously mentioned.

Experimental Values of U

Tests were made on the Pratt & Whitney 1340-H cylinder in which the engine conditions were held constant and the weight of cooling air was varied. The rate of heat dissipated from the head and barrel and the average head and barrel temperatures were obtained in the manner previously described and the values of U were calculated making use of Eq. (9). These values are plotted in Fig. 7 on logarithmic-coordinate paper against the weight flows W_b and W_h. From Fig. 7 the following equations are readily obtained.

$$\text{Head} \quad U = 0.1195\ (W_h)^{0.67}$$
$$\text{Barrel} \quad U = 0.1543\ (W_b)^{0.67}$$

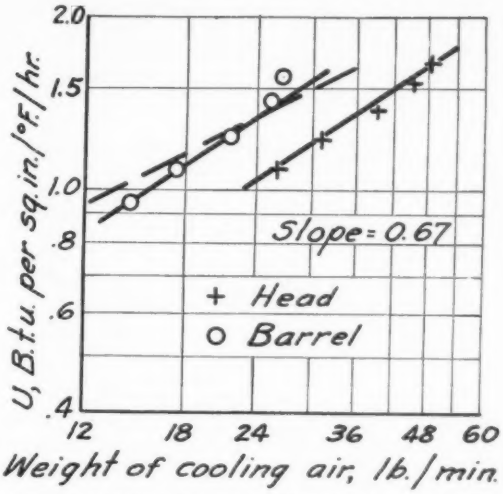

Fig. 7. Variation of heat-transfer coefficient of finned surfaces with the rate of cooling-air flow.

where U is in B.t.u./hr./sq. in./°F. and W_h and W_b are in lb./min.

The dotted curve in Fig. 7 represents the values of U for the barrel calculated by means of Eq. (11). The dimensions for the barrel fins are $w = 0.50$ in.; $s = 0.115$ in.; $t = 0.0257$ in.; $s_b = 0.11$ in. The thermal conductivity K for steel = 2.17 B.t.u./sq. in./hr./°F./in. The passage area between the barrel fins and the baffles is 3.177 sq. in. The values of q for a fin space s of 0.115 in. for various mass flows were obtained from reference 11.

ρV lb./sq. ft./sec.	q
3.72	0.0838
5.6	.1095
10.7	.169
12.5	.189
14.5	.207

An attempt was made to calculate the U for the head by considering an equivalent finned cylinder having the same average fin design, baffle, and cooling arrangement as the head. The curve obtained by plotting these calculated values in Fig. 7 coincided with the line representing the test values of U for the barrel. This line has the same slope as the line representing the test values of U for the head but gives values of U for the head 30 percent higher than the values obtained in the tests for the same weight flow of cooling air.

The heat dissipated from the head and barrel (see Eq. (9)) now becomes

$$\left.\begin{array}{ll}\text{Head} & H = 17.0\ (W_h)^{0.67}\ (T_h - T_a) \\ \text{Barrel} & H = 10.6\ (W_b)^{0.67}\ (T_b - T_a)\end{array}\right\} \quad (12)$$

where H is in B.t.u. per hour and W_h and W_b are in lb. per min. The heat transfer may be given in terms of $\Delta P\rho/\rho_0$ instead of W_h and W_T by making use of the

[10] Oscar W. Schey and Vern G. Rollin, *The Effect of Baffles on the Temperature Distribution and Heat-Transfer Coefficients of Finned Cylinders*, N.A.C.A. Technical Report 511, 1934.

[11] Oscar W. Schey and Herman H. Ellerbrock, Jr., *Blower Cooling of Finned Cylinders*, N.A.C.A. Technical Report in preparation.

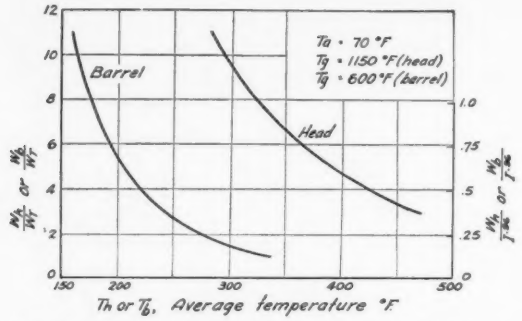

FIG. 8. Relation between engine and cooling condition to obtain various cylinder-head and barrel temperatures.

relation between these quantities shown graphically in Fig. 1. It may also be given in terms of the blower power and, for the present case, it is evident that the rate of heat transfer is proportional to the 0.22 power of the blower power for a constant temperature difference.

The following equations may now be obtained from Eqs. (12) and (8) for the average head and barrel temperatures:

$$\text{Head} \quad T_h - T_a = \frac{T_g - T_a}{3.26\dfrac{W_h^{0.67}}{I^{0.64}} + 1} = \frac{T_g - T_a}{0.82\left(\dfrac{W_h}{W_T}\right)^{0.67} + 1}$$

$$\text{Barrel} \quad T_b - T_a = \frac{T_g - T_a}{3.86\dfrac{W_b^{0.67}}{I^{0.64}} + 1} = \frac{T_g - T_a}{0.98\left(\dfrac{W_b}{W_T}\right)^{0.67} + 1} \tag{13}$$

Fortunately in the present case the curves (see Figs. 3 and 7) from which the exponents of W_h, W_b, and W_T were obtained were nearly enough parallel so that a common exponent could be obtained. In general, the exponents will not be identical although they should not greatly differ.

Eqs. (13) indicate that, if the ratio of the weight of air passing around the cylinder to the weight of air passing through the cylinder (corrected to include residuals), is held constant then the average cylinder temperatures remain constant. It is also apparent that, if the cooling-air weight is increased in the same ratio as the indicated horsepower, then the average cylinder temperatures remain practically constant. It should be noted that the foregoing equations were obtained from engine tests in which no detonation could be heard.

Fig. 8 shows the ratio of W_g to W_T and W_b to W_T to obtain various average head and barrel temperatures calculated from Eqs. (13) for the values of T_g and T_a given in the figure. The relationship between the cooling-air weights and the indicated horsepower is also indicated on the curve.

There is no definite relation between the maximum and average cylinder temperatures. Even for the same cylinder it varies for various baffle arrangements and methods of cooling. In the present case the baffles fitted the cylinder closely only from the 90° position to the rear of the cylinder. The temperature at the rear of the barrel was about 30°F. higher than the average barrel temperature, and the highest head temperature occurring between the rear spark plug and the exhaust port varied between 120°F. and 150°F higher than the average head temperature. An estimate of the variation in maximum cylinder temperatures may be obtained from the variation in the average temperatures.

Eqs. (13) and the curves for T_g provide a means of obtaining the effect of the fundamental engine and cooling variables on the average cylinder temperatures. For example, by differentiating T_h and T_b in Eqs. (13) with respect to T_a simple expressions may be obtained for the increase in head and barrel temperatures per °F. increase in cooling-air temperature. The values of these derivatives calculated from the foregoing expressions fall between 0.77 and 0.83 for the head and 0.71 and 0.76 for the barrel for a range of engine and cooling conditions. These values check very well with the values obtained in tests on the effect of cooling-air temperature on cylinder temperature for a constant mass flow of cooling air.

Effect of Slipstream on the Longitudinal Stability of a Low Wing Monoplane*

C. M. BOLSTER, *Naval Air Station, Pensacola*

Presented at the Flying Properties and Flight Session, Fifth Annual Meeting, I. Ae. S. January 29, 1937

THE following investigation was carried out last year at the California Institute of Technology. The one-sixth scale self-propelled model used by J. S. Russell and H. M. McCoy[1] was available and it was a relatively simple matter to convert it from a high wing to a low wing configuration. A three-bladed fixed pitch propeller having Hamilton Standard 1A1-O blade form with 10% of each blade cut off at the tip was used, blades being set at 29° at three-quarter radius. Fig. 1 illustrates the important features of the model.

The propeller was driven electrically by a motor of approximately one thirty-sixth full scale power. Propeller revolutions were six times their full scale value and therefore the velocity of each blade element closely approximated its full scale amount. Power was measured by counting the revolutions over a ten second interval and simultaneously reading the torque. The torque mechanism consisted of an Alternating Current Wheatstone Bridge, propeller torque acting against springs and moving a soft iron armature relative to two coils, the impedances of which were balanced one against the other. The springs, armature, and coils are shown in Fig. 2.

For this investigation, accurate calculation of the power was only necessary insofar as it was required in controlling the power range to be used in carrying out the tests. The "power required" and "power available" curves of a comparable full scale airplane were used as a guide in making each run, power on the model being varied to give several readings from a value less than that required to more than that available.

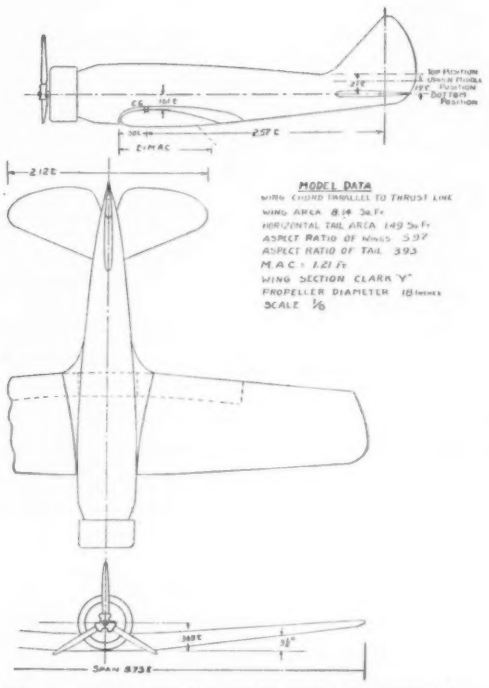
MODEL DATA
WING CHORD PARALLEL TO THRUST LINE
WING AREA 8.14 Sq. Ft.
HORIZONTAL TAIL AREA 1.49 Sq. Ft.
ASPECT RATIO OF WINGS 5.97
ASPECT RATIO OF TAIL 3.93
M.A.C. = 1.21 Ft.
WING SECTION CLARK Y
PROPELLER DIAMETER 18 INCHES
SCALE 1/6

FIG. 1. Power model showing principal dimensions.

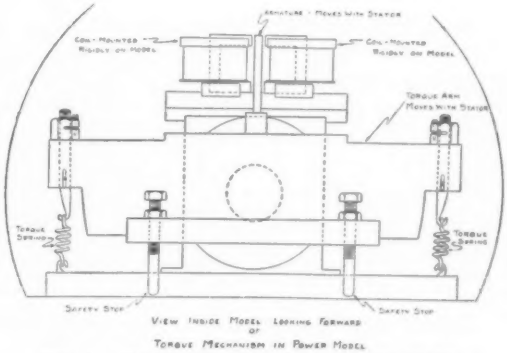

FIG. 2. Torque measuring device, power model.

PURPOSE AND PROCEDURE

The purpose of this investigation was to measure the change in the slope and intercept of the moment coefficient-lift coefficient curves resulting from the presence of the slipstream. Some method by which this change could be forecast when only the unpowered wind-tunnel curves were available was sought.

Tests were made with the horizontal stabilizer in the three different vertical positions shown in Fig. 1. Later, flaps were put on the model and runs were made with the horizontal stabilizer in the top and bottom position. In order to make it possible to separate

* The opinions expressed in this article are those of the author and are not to be construed as reflecting the views of the Navy Department. In publishing this paper the author wishes to acknowledge the aid given during the performance of the experimental work by M. K. Fleming, U. S. N., the wind-tunnel personnel at GALCIT, and Clark B. Millikan.

[1] J. S. Russell and H. M. McCoy, *Wind Tunnel Tests on a High Wing Monoplane with Running Propeller*, J. Ae. S., Vol. 3, No. 3, January, 1936.

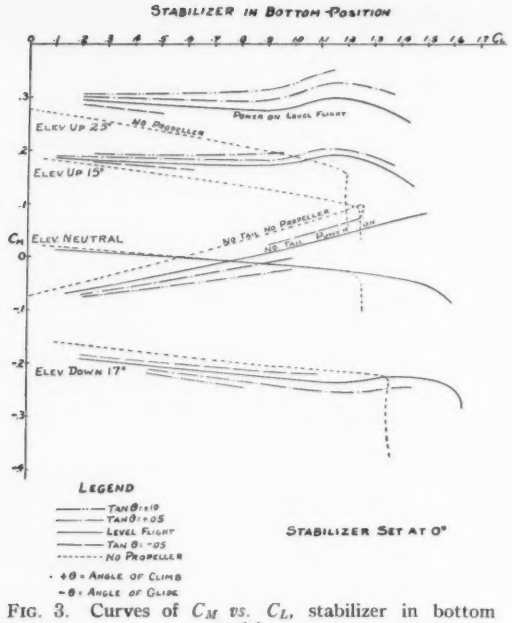

FIG. 3. Curves of C_M *vs.* C_L, stabilizer in bottom position.

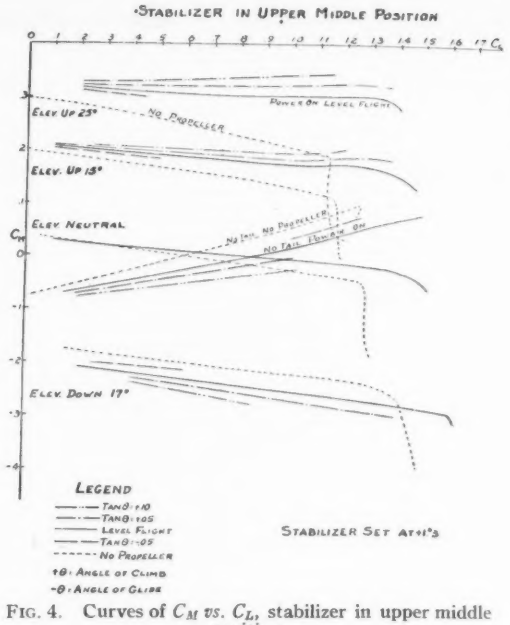

FIG. 4. Curves of C_M *vs.* C_L, stabilizer in upper middle position.

each moment coefficient curve of the complete model into the portion due to tail surfaces and that due to wing and fuselage, it was also necessary to test the model without any tail surfaces both with and without the propeller running.

PRESENTATION OF RESULTS

In presenting the results of such an investigation some convenient method of indicating the relative amount of slipstream acting is necessary. The one used was suggested by C. B. Millikan and expresses the propeller output in terms of the angle of climb or glide which an airplane would have were it in flight with an equivalent thrust acting under the given conditions of airspeed and angle of attack. Thus, in the wind tunnel with a propeller thrust acting, a resultant drag coefficient C_R is obtained. If θ represents the angle of climb of the airplane, the resultant thrust equals $W \sin \theta$, and the lift equals $W \cos \theta$. Therefore, $-C_R/C_L$ equals the tangent of the angle of climb and tangent θ makes a convenient parameter for expressing the amount of slipstream acting under the given conditions.

SLIPSTREAM EFFECTS ON COMPLETE AIRPLANE

The effect of slipstream on the longitudinal stability of the complete airplane does not lend itself to analysis until it is broken down into wing-fuselage effects and tail effects. However, it is interesting to note the variations in the shape of the moment coefficient curves with different vertical positions of the horizontal stabilizer. As the vertical position was changed, the stabilizer setting was altered just enough to trim the airplane at

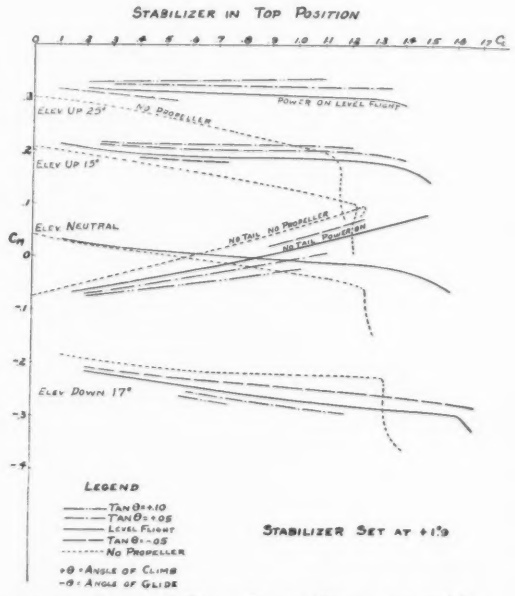

FIG. 5. Curves of C_M *vs.* C_L, stabilizer in top position.

the same lift coefficient. The curves of C_m *versus* C_L for the complete airplane without flaps are shown in Figs. 3, 4, and 5. The predominant feature of these curves is the appearance of an unstable region near the stall with slipstream acting when the stabilizer is in the bottom position. This has completely disappeared in the top position. The curves obtained without propeller show no indication of such a condition.

Figs. 6 and 7 show the same comparison with flaps down. Although a similar difference in the curves is

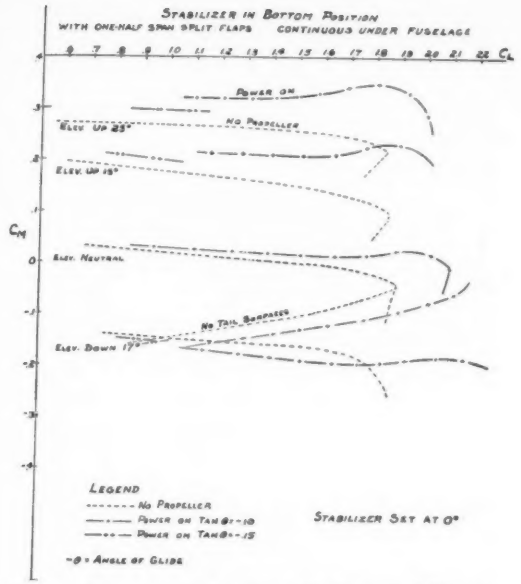

FIG. 6. Curves of C_M vs. C_L, with flaps, stabilizer in bottom position.

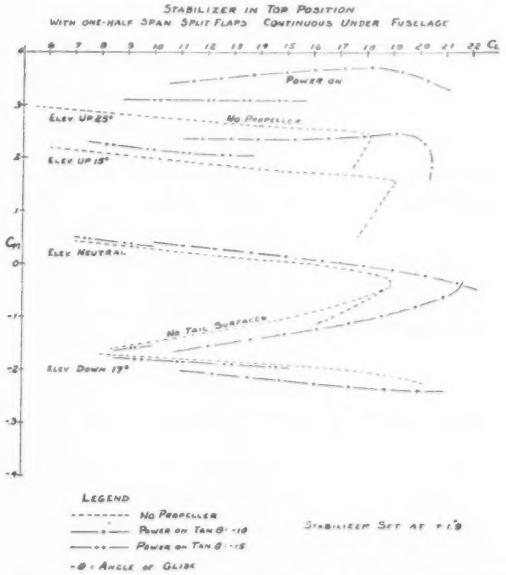

FIG. 7. Curves of C_M vs. C_L, with flaps, stabilizer in top position.

evident, it is not as pronounced, an unstable tendency appearing in both the top and bottom position of the stabilizer.

SLIPSTREAM EFFECTS ON WING AND FUSELAGE

The static longitudinal stability of an airplane may be expressed in the form: $C_m = C_{m_w} + C_{m_f} + C_{m_t}$ where the subscripts indicate the portions of moment coefficient due to wing, fuselage, and tail, respectively. Consider first the portions due to wing and fuselage which for present purposes are combined into one coefficient $C_{M_{wf}}$:

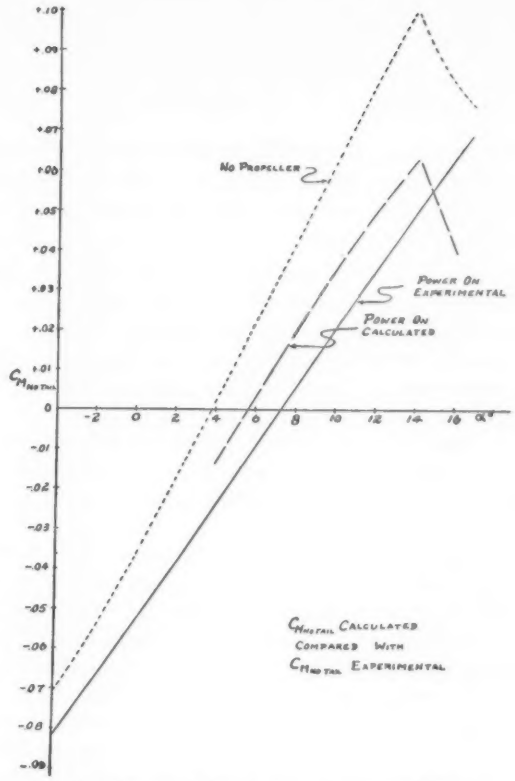

FIG. 8. Curves of $C_{M\ \text{no tail}}$ vs. α, measured and computed.

$$C_L = \frac{\text{Lift}}{qS} \qquad C_M = \frac{\text{Moment}}{qSt}$$

C_{M_e} (portion affected by slipstream) $= C_{M_0} + \left(\frac{d}{t} - \frac{h}{t}\right) C_{L_e}$ where d and h represent distances from leading edge of wing to *C.G.* and mean aerodynamic center, respectively.

It has been assumed here that slipstream effects have not changed C_{M_0} and h/t. Actually some change has probably occurred.

With slipstream acting the wing-fuselage moment coefficient $C'_{M_{wf}}$ consists of three portions,

(1) that portion in the slipstream $\Delta C'_{M_1}$

(2) that portion due to thrust $\Delta C'_{M_2}$

(3) that portion not affected by slipstream $\Delta C'_{M_3}$.

The moment on the portion affected by the slipstream,

$$M_e = C_{M_e}\, q_e S_e t_e = \left[C_{M_0} + \left(\frac{d}{t} - \frac{h}{t}\right) C_{L_e} \right] q_e S_e t_e \text{ and}$$

$$\Delta C'_{M_1} = \frac{M_e}{qSt}$$

$$\Delta C'_{M_2} = \frac{M_{th}}{qSt} \text{ where } M_{th} \text{ is moment due to thrust.}$$

$$\Delta C'_{M_3} = \frac{C_{mqt}(S - S_e)}{qSl}$$

$$C'_{M_{wf}} = \Delta C'_{M_1} + \Delta C'_{M_2} + \Delta C'_{M_3}$$

A curve of $C'_{M_{wf}}$ has been calculated by this method, the results being shown in Fig. 8. The experimental $C'_{M_{wf}}$ curve does not agree with the calculated curve. The experimental results for $C_{M_{wf}} - C'_{M_{wf}}$ appeared approximately 1.7 times the calculated values. The present experimental results, therefore, suggest that in order to approximate the wing-fuselage moment coefficient curve with slipstream acting for other similar airplanes without new tests the calculated values be multipled by 1.7.

In calculating the wing moment coefficient in the portion affected by slipstream, it is necessary to estimate the lift coefficient which is acting on the portion of the wing in the slipstream.

Let propeller diameter = D_p; assume that at the wings with no fuselage present, slipstream diameter would have contracted to D_0 where $\pi D_0^2/4 = .8\pi D_p^2/4$. With fuselage in slipstream, its cross-sectional area will remain $\pi D_0^2/4$, but its actual diameter D_S is greater due to the fuselage, that is $\pi D_0^2/4 = (\pi D_s^2/4 - (\pi D_F^2/4)$. The span of the portion of the wings in the slipstream will be $D_S - D_F$ and the wing area in the slipstream becomes $(D_S - D_F)t_e$. In level-flight propeller thrust $T = \frac{C_D q S}{\cos \alpha}$ and propeller thrust coefficient $C'_T = \frac{T}{q\frac{\pi D_0^2}{4}}$.

Referring to "Aircraft Propeller Design" by Weick, page 9, C'_T may also be written, $C'_T = 4a(1 + a)$ where $2a$ is the increment of increase in slipstream velocity over flight velocity. It has been assumed here that abreast the wing the slipstream has contracted to eight-tenths the propeller disc area and that the slipstream velocity equals $V(1 + 2a)$.

$$\Delta V_s = V \times 2a;\ V_s = \sqrt{(V + \Delta V_s \cos \alpha)^2 + (\Delta V_s \sin\alpha)^2}$$

$$\text{Tan } \Delta\alpha = \frac{\Delta V_s \sin \alpha}{V + \Delta V_s \cos \alpha}$$

$$q_e = {}^1/_2 \rho V_s^2$$

C_{L_e} = Lift coefficient at $\alpha - \Delta\alpha$

It is a simple matter now to calculate the resultant lift coefficient acting on entire wing while the slipstream is present. Let $L' = \Delta L_1 + \Delta L_2 + \Delta L_3$, where these symbols represent the portions of lift due to part of wing in slipstream, vertical component of thrust and part of wing not in slipstream, respectively.

Then $\Delta L_1 = q_e S_e C_{L_e}$

$\Delta L_2 = T \sin \alpha$

$\Delta L_3 = (S - S_e)\, C_L q$

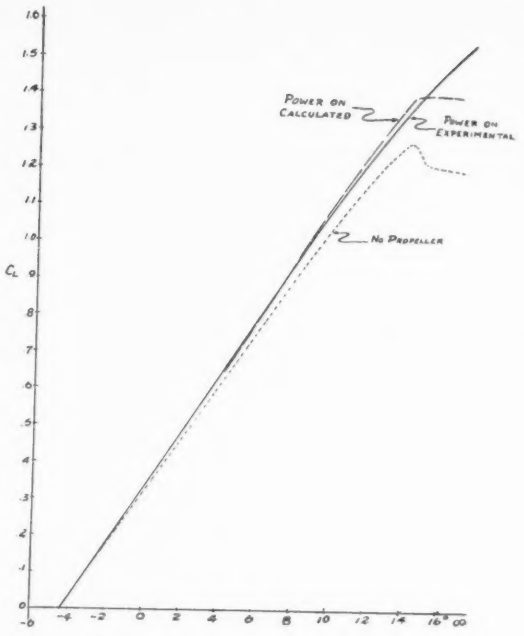

FIG. 9. C_L *vs.* α, with power, measured and computed.

and $C'_L = \frac{\Delta L_1 + \Delta L_2 + \Delta L_3}{SC_L q}$

Calculated and experimental values of C'_L *versus* α are shown in Fig. 9.

Slipstream Effects on Tail Moments

C. B. Millikan has proposed that the tail moment coefficient may be expressed in the form:

$$C_{M_t} = -\eta_t \frac{l}{t}\frac{S_t}{S}\left[\frac{1 - \frac{a_0}{\pi \text{AR}}}{1 + \frac{a_0}{\pi \text{AR}_t}} C_L - \frac{a_0}{1 + \frac{a_0}{\pi \text{AR}_t}}\, \alpha_d\right]$$

In writing this equation the following simplifying assumptions have been made.

(a) The wing is assumed to have an elliptical lift distribution.

(b) The down wash at the tail is assumed to be twice that at the wing.

(c) A tail efficiency factor η_t is introduced to correct for effective velocity at tail and other errors due to simplifying assumptions used.

Differentiating with respect to C_L,

$$\frac{dC_{M_t}}{dC_L} = -\eta_t \frac{l}{t}\frac{S_t}{S}\left[\frac{1 - \frac{a_0}{\pi \text{AR}}}{1 + \frac{a_0}{\pi \text{AR}_t}}\right]$$

where η_t is the only unknown. Its value can be readily

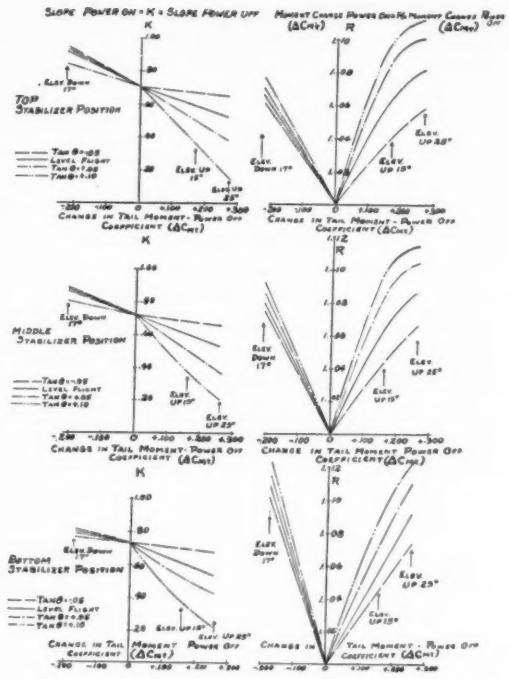

FIG. 10. C_{M_t} corrective factors for slipstream, K and R *vs.* ΔC_{M_t}.

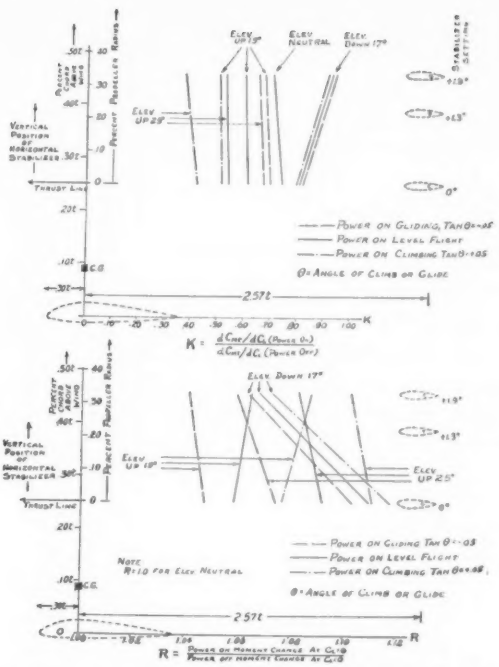

FIG. 11. C_{M_t} corrective factors for slipstream, K and R *vs.* vertical position of horizontal stabilizer.

determined graphically by taking the slope of the C_{M_t} *versus* C_L curve. If the values of moment coefficient for wing and fuselage alone are subtracted from the values obtained for the complete airplane, tail moment coefficients will be obtained.

The effect of slipstream on tail moment coefficient curves consists of a change in slope, and a change in the intercept for any deviation of the elevator from a neutral position.

If $\frac{dC'_{M_t}}{dC_L}$ represents slope with slipstream acting, and $\Delta C'_{M_t}$ expresses the change in moment intercept due to elevator angle with power on, we may write

$$\frac{\frac{dC'_{M_t}}{dC_L}}{\frac{dC_{M_t}}{dC_L}} = K,$$ where K shows ratio of slope power on to slope power off.

Similarly let $R = \frac{\Delta C'_{M_t}}{\Delta C_{M_t}}$, where R expresses ratio of moment intercept power on to that power off. Then the tail moment coefficient with slipstream acting becomes:

$$C'_{M_t} = -\eta_t \frac{l}{\bar{l}} \frac{S_t}{S} \left[K \frac{1 - \frac{a_0}{\pi \, \mathrm{AR}}}{1 + \frac{a_0}{\pi \, \mathrm{AR}_t}} C_L - R \frac{\frac{a_0}{1 + \frac{a_0}{\pi \, \mathrm{AR}_t}}}{} \alpha_d \right]$$

Values of K and R obtained from the tests without flaps using that portion of the tail moment coefficient below a lift coefficient of 1.0, have been plotted in Figs. 10 and 11. In Fig. 11 the variation of these factors with vertical position of the horziontal stabilizer is shown.

APPLICATION OF RESULTS TO WIND-TUNNEL TESTS

Assuming that the wind-tunnel model of a proposed design has been tested with and without tail surfaces, curves of $C_{M_{wf}}$ and C_{M_t} *versus* C_L should be available. The "power on" curve of $C'_{M_{wf}}$ can be estimated as previously explained. In order to obtain C'_{M_t}, values of K and R must be obtained from Fig. 10 or 11 for the desired power condition, elevator setting and vertical position of horizontal stabilizer. These values must be corrected for the relative amount of horizontal tail area exposed to the slipstream.

If S_{t_e} = horizontal tail area exposed to slipstream

S_t = horizontal tail area

$$K \text{ corrected} = 1 + \frac{S_{t_e}/S_t(K-1)}{(S_{t_e}/S_t)_{\text{tested}}}$$

$$R \text{ corrected} = 1 + \frac{S_{t_e}/S_t(R-1)}{(S_{t_e}/S_t)_{\text{tested}}}$$

But $(S_{t_e}/S_t)_{\text{tested}} = .67$

$$K \text{ corrected} = 1 + \frac{S_{t_e}/S_t}{.67}(K - 1)$$

$$R \text{ corrected} = 1 + \frac{S_{t_e}/S_t}{.67}(R - 1)$$

Conclusions

(1) Calculated values of C'_L agree closely with experimental "power on" results.

(2) Calculated values of $C'_{M_{wf}}$ do not agree with experimental values quantitatively; the observed slipstream influence is approximately 1.7 times the calculated value.

(3) Slipstream improves the stability of the wing and fuselage alone in a low wing monoplane.

(4) Slipstream decreases the slope of the tail moment coefficient curves as amount of power is increased.

(5) Slipstream increases the moment caused by a movement of elevator from neutral to either an up or down position.

(6) Near the stall, slipstream creates an unstable region in the tail moment coefficient curves, when the horizontal stabilizer is on or near the thrust line. This disappears if the stabilizer is located relatively as high as the top position used in this investigation. Presumably higher positions would also be satisfactory.

(7) With split flaps set at 45°, slipstream decreases the stability in power on gliding flight. The effect is less when the stabilizer is mounted in the top position.

Book Reviews

Zeppelin, by Captain Ernst A. Lehmann; Longmans Green & Company, New York, 1937; 365 pages, ill., $3.00.

Everyone who reads this work will understand more fully the great loss to aeronautics through the death of Captain Lehmann. It is not only a history of the development of the Zeppelin type of airship but its biographical pages give an outline of Lehmann's experience and the great vision this group of pioneers, who through triumph and defeat, held to their convictions as to the possibilities of this type of aircraft. It was written to mark the completion of a successful transatlantic season, but the sense of tragedy grips the reader who knows the end that was not forseen by the author.

None of the earlier books on the Zeppelin have had the personal viewpoint of this volume. The part played by German airships during the war is given without any attempt to minimize the losses. Probably for the first time readers will understand the great pressure brought to bear on the constructors and operators of airships by the German General Staff to do the impossible and how exploits were undertaken which were bound to have an inevitable ending.

The gradual expansion of the Zeppelin organization from its beginnings is told with an intimate knowledge of the plans and policies of the people who formed the determined group. Word pictures of Count Zeppelin, Dr. Dürr, Dr. Eckener and the other participants in the development bring a new realization of their great ability to overcome difficulties.

Captain Lehmann had been in command of airships during 1075 flights before his Hindenburg experience. The book gives vivid accounts written with great human interest of the flights of the Graf Zeppelin and the Hindenburg.

No one could have written a concluding chapter to Captain Lehmann's book as well as Commander C. E. Rosendahl. Their intimate association and friendship which extended over many years gave him an opportunity to write a description of the tragic end of such a great career with that spirit of carrying on which would have been precisely what Captain Lehmann would have wished.

The Physical State of the Upper Atmosphere, by B. Haurwitz; Journal of the Royal Astronomical Society of Canada, 1937.

In this report, Dr. Haurwitz gives a convenient summary of all the principal methods by which we derive information about the state of the upper atmosphere. Starting with a discussion of the observations on mother-of-pearl clouds and noctilucent clouds, he takes up in succession the subjects of meteors, the light of the night sky, the propagation of electric waves and ionization, the diurnal variations of terrestrial magnetism, the aurora, ozone, the anomalous propagation of sound and, finally, the composition and structure of the atmosphere. Each of the above phenomena tells its story about the state of certain regions of the upper atmosphere and it is the first time that the complete body of available information is brought before us. The evidence being mostly of an indirect nature, it is natural to find conflicting opinions in the interpretation of the results. Credit is due to the author for having given honorable mention to some theories, which on account of their obviously speculative nature, have as yet not called forth close scrutiny.

The last chapter is followed by a concise summary, a feature which would be welcomed in the preceding chapters.

To one who desires to obtain a comprehensive view of our knowledge and of the outstanding problems of the upper atmosphere, this report is highly recommended. The bibliography at the end will prove useful to research workers in the field. The Blue Hill Meteorological Observatory of Harvard University, at Milton, Massachusetts, has a supply of reprints which may be obtained for $.50.

C. L. Pekeris
Massachusetts Institute of Technology

The GALCIT Radio Meteorograph

O. C. MAIER* and L. E. WOOD, *California Institute of Technology*

Presented at the Instruments, Radio and Radio Meteorograph Session, Fifth Annual Meeting, I. Ae. S., January 27, 1937

Introduction

WORK on the radio meteorograph was begun at the California Institute of Technology by E. S. Mathews in the fall of 1934. A five-meter transmitter and receiver were built by him. The writers have carried on the work from the summer of 1935 to date. A 4.7 meter transmitter was flown at Kelly Field, Texas, in August by Victor Neher and reached an altitude of 38,000 ft. Reception lasted one hour when it is presumed the batteries froze. This flight, although successful, showed the need for a complete revision of the instrument for the following reasons:

(a) Man-made disturbances interfere with reception and the making of a record.

(b) No satisfactory directional antenna could be used for plotting wind direction, because size would be prohibitive.

(c) Limited range with low efficiencies, 16 percent.

(d) Battery weight excessive and required too much insulation.

The objectives were to build a complete instrument weighing less than one pound, a single directional receiving antenna system, a more efficient power supply less subject to temperature changes, and to use a frequency band above the normal natural and artificial interference range.

Transmitter

The transmitter operates on a wave-length of 1.67 meters and power output of about 0.5 watts. The circuit used is a Colpitt's oscillator as shown in Fig. 1. A more stable, tuned pipe-line transmitter is in the process of construction but has not as yet been tested. This wave-length was chosen because it could be generated efficiently by the "acorn" type tube, and permitted small but good directional receiving systems to be built. The circuit is simple and readily tuned. The frequency drift at high altitudes is less than .003 meters as measured on the receiver. The weight of the transmitter alone is two ounces.

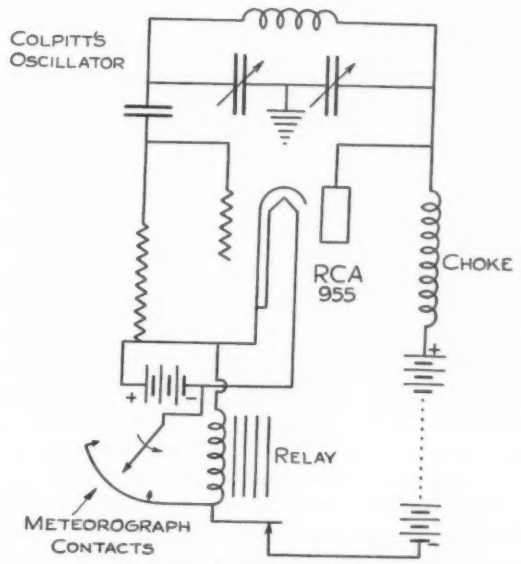

Fig. 1. Transmitter circuit.

Keying System

Keying is accomplished as shown in Fig. 1. A rotating arm makes contact in turn with reference point, pressure, temperature, and humidity arms. It will be noted that in contrast to other systems, transmission ceases when contact is made. This is effected by the relay. A continuous signal is required as an aid in direction finding.

Power Supply

Special dry cells were used in the first model but had poor shelf life, poor current characteristics, and undesirable temperature characteristics. The next batteries used were small storage batteries built to specification in October, 1935. These cost considerably more and were not satisfactory for plate batteries. The requirements are 120 volts for the plate and 12 milliamperes current, for the filament 6.3 volts and 150 milliamperes current. At the California Institute storage batteries have been developed of the lead-acid type having the advantage of light weight and small voltage drop at low temperatures. The batteries are constructed by cutting small plates from large battery plates and forming cell cases of rubber tape. A "U" shaped celluloid separator is used to prevent the plates

* Assigned to the meteorological course from the Signal Corps. The authors wish to acknowledge the valuable counsel of the GALCIT staff and to thank Dr. Potapenko of the Physics Dept. for his helpful suggestions in connection with the radio development.

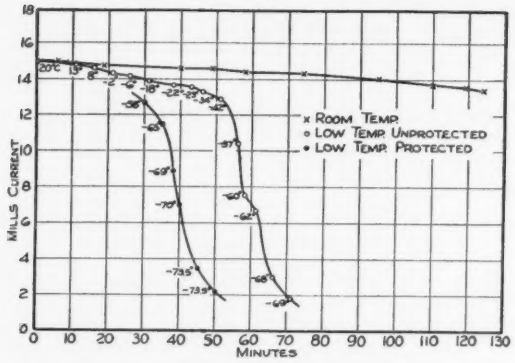

FIG. 2. Plate battery performance curves

from touching. One positive and one negative plate are used for each cell.

Plate batteries capable of giving 13.5 to 15 milliamperes steadily for two hours weigh from 1.35 to 1.45 grams per volt. Thus a 120 volt battery weighs about 168 grams. A 6.3 volt filament battery designed to supply 150 milliamperes for the filament and the adtional current needed for the keying relay weighs from 70 to 80 grams. The batteries are filled with acid immediately before charging and are charged for one hour prior to use. They have shown themselves to be very reliable and satisfactory in use.

The curve designated "room temperature" in Fig. 2 shows a discharge test of two plate cells of the type described above. The discharge was started at 15 milliamperes and was 13.5 milliamperes at the end of two hours. The curve marked "low temperature unprotected" shows the effect of low temperature on the cells. The discharge was started at 15 milliamperes and when the temperature reached −42°C. was still 12.7 milliamperes. At −57°C. it was 10.3 milliamperes or over two-thirds its original value. This indicates that the batteries are good to about −50°C. when unprotected in any manner, and has been verified by flights made both day and night with unprotected batteries, during which flights temperatures of −50°C. were recorded satisfactorily but the signals faded out as the temperature dropped lower. A test was then made in the laboratory with the batteries enclosed in a celluloid box whose walls were .01 in. thick. The curve marked "protected" shows the results. This indicates that the celluloid case furnishes enough protection to enable the batteries to operate through an additional drop of 10°C. to 15°C. This means that at night they would be good to −60°C. to −65°C. During the day the effect of the celluloid case would probably be much greater and keep the batteries warm under any conditions encountered in the atmosphere. In the latter two curves showing battery discharge at low temperatures, the time is of little significance, as the drop is due to the temperature effect.

With continued development and the use of thinner rubber for cases, it is believed that the battery weight can be reduced somewhat below that given above.

RECEIVER

The receiver circuit is shown in Fig. 3. The circuit is super-regenerative with one radio frequency stage of amplification. There are very few successful receivers in this region of the radio spectrum and many models

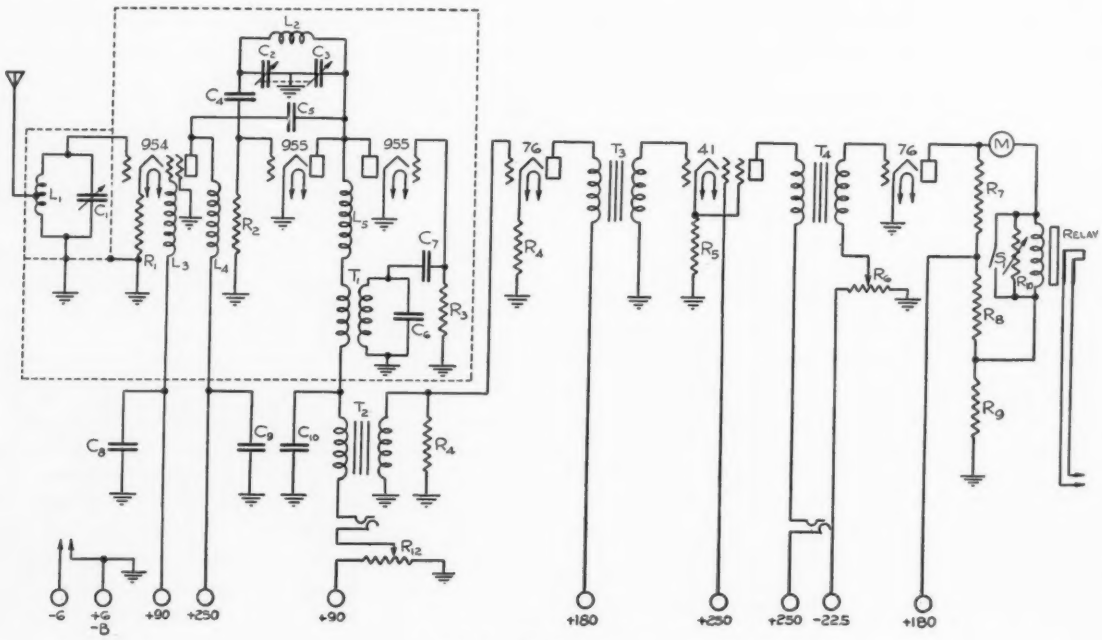

FIG. 3. Receiver circuit.

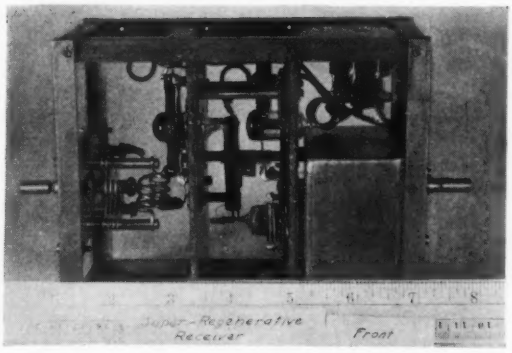

FIG. 4. High-frequency assembly of receiver.

were built. Glen Peterson of the California Institute joined the authors in this work. The excellent performance of the present model is due to him.

The receiver acts as follows: When a signal is received it is first amplified, then fed to the super-regenerative circuit which is quenched by a 100 kilocycle oscillator. Since the input is a continuous wave, there is no audible signal, and the net result to the audio amplifier is to reduce all background noises to zero. As the signal is cut off by the relay in the transmitter, the noise level is restored to normal. This surge of current is rectified by the square law detector and amplified to operate the relay shown to the right. The bridge network surrounding it balances out local impulses not due to the transmitter and permits fine adjustment of the sensitive relay. This in turn operates a relay on the recorder.

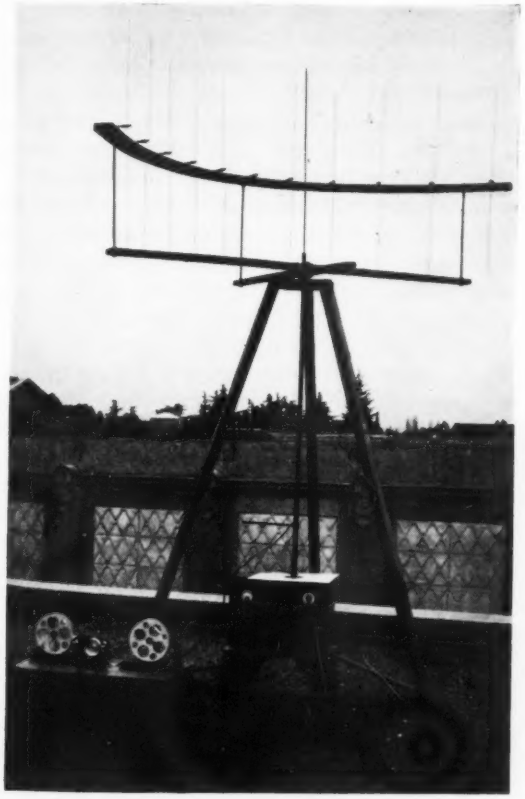

FIG. 5. Receiving station.

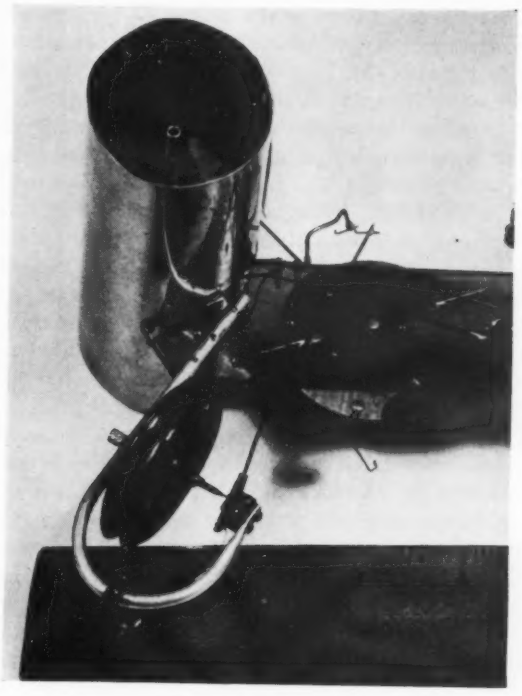

FIG. 6. Meteorograph.

The high-frequency assembly is shown in Fig. 4. Of major importance to satisfactory operation is the compact and precise arrangement of its parts. All parts were designed especially for a given function. The high-frequency amplifier is in the shield can in the lower right-hand corner. The receiver has eight sets of coils to cover the range from .63 to 3.23 meters. So far no interference has been heard of static, X-ray, diathermy, or ignition source. Of course, batteries are used as power supply.

DIRECTION FINDER

A parabolic directional antenna is shown in Fig. 5. This type was chosen because of its amplification factor of seven on the input signal, small number of elements required, and good angular definition ($\pm 2.5°$C. average accuracy for azimuth angles as checked against theodolite readings). The next step is to measure elevation angles simultaneously with the azimuth angles. Mr. Easton of the California Institute has taken over this part of the problem recently.

METEOROGRAPH

A meteorograph for measuring pressure, temperature, and relative humidity is shown in Fig. 6. A special watch movement turns a double-ended arm at a

constant rate. Each end of the arm is equipped with a contact wire, a complete series of measurements being made for each half turn of the arm. Fixed contacts with which the rotating arm makes contact as it turns are provided for reference points. Each metric element is connected to actuate an arm provided with a contact on its end. The position of this arm is a measure of the element under consideration. In Fig. 6 the temperature and humidity measuring arms can be seen projecting from the radiation shield and extending across the watch movement while the pressure arm can be seen in its entirety. As the rotating arm turns, it makes contact in a regular sequence with the fixed and movable contacts, thus measuring the time intervals between them.

In order to give accurate measurements, the watch movement or whatever type of timing device is used, must turn the contact arm with a smooth, steady motion, furnish sufficient power for making contacts and operate at any temperature to which it will be exposed in the upper atmosphere. Also it must turn fast enough to give the desired frequency of measurements. The ordinary watch ticks about five times a second and consequently furnishes a very jerky motion if the second hand shaft is used for operating contacts; also, the power available is very small.

In order to overcome the disadvantages inherent in a regular watch movement, modifications have been made that greatly increase the smoothness of motion and the power available for making contacts. Inexpensive pocket watches that normally tick 272 times a minute are changed by eliminating one gear from the gear train, shortening the hairspring and lightening the balance wheel. By this means, the rate of ticking has been increased to as much as 1360 times a minute. The gearing is such that there are 2040 ticks per turn of the center wheel of the watch to which the hour hand is normally fastened. When timed to tick 1020 ticks per minute, the center wheel turns once every two minutes. The rotating contact arm is fastened to this wheel, and since each end is provided with a contact, one complete series of observations is made each minute. A watch ticking 1360 times a minute gives a series of observations every 45 seconds. The modified watches run approximately one hour on a winding, using up the entire energy of the mainspring in that period. However, the length of operation can be varied to suit the need. Both extra long mainsprings and two mainsprings connected in series have been successfully tried, giving periods of operation up to three hours.

Torque measurements made on modified watches show a torque of at least 30 gram-centimeters available at the center wheel when almost run down. The center wheel is driven directly from the mainspring barrel so that the power is taken off close to the high torque end of the gear train. Torque measurements on the second-hand shaft of an unmodified watch gave .3 of a gram-centimeter. However, this value is considered somewhat questionable due to the jerkiness of the motion, making measurement difficult.

With respect to operation at low temperatures, the modified watches are very satisfactory. A number of different watches has been tested at low temperatures, and they operate reliably from room temperature to below $-70°C$. No protection from the cold is necessary to keep them running. Usually they are oiled with kerosene prior to exposure to low temperature.

Extensive tests made both at room temperature and at low temperature show that the accuracy of the modified watches is sufficient to give good measurements. In a representative case, a watch was started at room temperature and was run down 71 minutes later at a temperature of $-57.5°C$. Every 90 seconds its rate of running was checked by letting it measure the interval between two fixed contacts. The interval was nine seconds, and the average deviation from a constant value was $1/32$ of a second. This and similar tests show that large temperature changes and the decrease in tension in the mainsprings, as they unwind, do not destroy the value of the watches for use in meteorographs. The rates of running change slightly with changes in temperature and tension in the mainsprings, but these changes are small and can easily be allowed for by calibrating under conditions comparable to those encountered in the atmosphere. Also, all measurements are made of short time intervals, the longest being of the order of 30 seconds, so that changes in rates of running cannot cause large errors to accumulate. For this reason, two reference points are generally used.

Successive pressure calibrations over a range in excess of 850 millibars have checked with an average error of less than two millibars. This includes all errors in the watch, contacts, pressure cell, and recording system. Temperature measurements are accurate to half a degree Centigrade except at extremely low temperatures when the errors may increase slightly. Relative humidity calibrations made over a month apart have checked within less than 2.5 percent. In all cases, the errors given are gross errors including the entire system of metric elements, contacts, watch, and recorder. Only part of the errors are due to the watch.

The contact system used is shown in Fig. 6. The rotating arm is rigid in the plane of rotation and flexible perpendicular to it. The contacts are of platinum wire. The fixed contacts and those connected to the metric elements are mounted sloping so that the rotating arm, upon making contact, bends down and passes under. Measurements are made between the instants of making of the two contacts between which measurement is desired. Consequently, the duration of contact is of little importance. Also, no friction is introduced into the metric system as the arms attached to the metric elements are perfectly free up to the instant of contact. Furthermore, as the movements of the metric elements are sufficient to actuate the arms

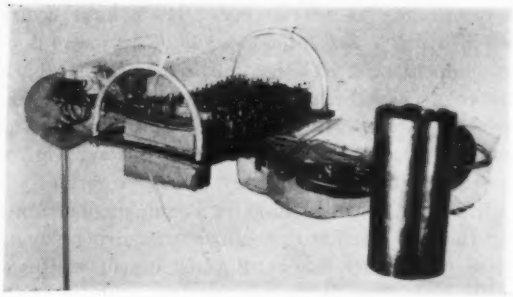

FIG. 7. Complete radio-meteorograph.

over the range of measurement, no complicated lever system is necessary. The pressure cells are the type used in airplane altimeters, the temperature bimetal is .005 in. thick, and for humidity a bundle of four to six hairs about 3 in. long is used.

The contacts are large, rugged, and not easily bent or otherwise damaged. Calibration and tests on the accuracy of the watches are all made with contacts of the type used in final instruments and show that friction in the contacts does not seriously affect the rate of running of the watches.

RECORDER

A constant speed tape recorder, shown in the lower left-hand corner of Fig. 5, is used in which the tape is driven by a synchronous motor. Various tape speeds can be obtained by the use of different sized driving drums. In general, a tape speed of one meter a minute is used. In normal use, the motor is driven by commercial a.c. current. Its accuracy has been checked against a.c. current whose frequency was controlled by a tuning fork and the errors found to be of the order of two- to three-tenths of a millimeter on the tape, which is less than the smallest division to be measured by the meteorograph. A pen fastened to a relay draws a straight line on the tape when no measurement is being made. When a contact is made, the relay pulls the pen to one side, making a jog in the line on the tape. When contact is broken, the pen goes back to its original position. It is only necessary to measure the distance between two successive breaks and then compare this with a calibration curve to get the desired value. The record can be evaluated as fast as received.

The arrangement of the contacts is such that pressure, temperature, and humidity measurements always come in a regular sequence, its being impossible for the order to change. This lessens the chance of confusion of the signals. Also, the pressure and temperature signals always come approximately the same time interval apart, so that it is easily known to what pressure each temperature corresponds.

COMPLETE ASSEMBLY

Fig. 7 shows an instrument ready for ascent. The batteries are in the center, the radio on one side, and the meteorograph on the other. Thus the instrument is divided into three components, each in its own celluloid case and each readily removable without disturbing the others. The weights of the various parts are approximately as shown in the following table:

Radio transmitter with case and antenna	60 grams
Battery case	25 "
"A" battery	80 "
"B" battery	170 "
Meteorograph with case	90 "
Total weight	425 grams

The actual weight of individual instruments may vary from slightly less than 400 to 450 grams but is consistently less than one pound (453.6 grams). A parachute and connecting cord weighing about 60 grams are used so that the gross weight lifted by the balloon in excess of its own weight is about 500 grams.

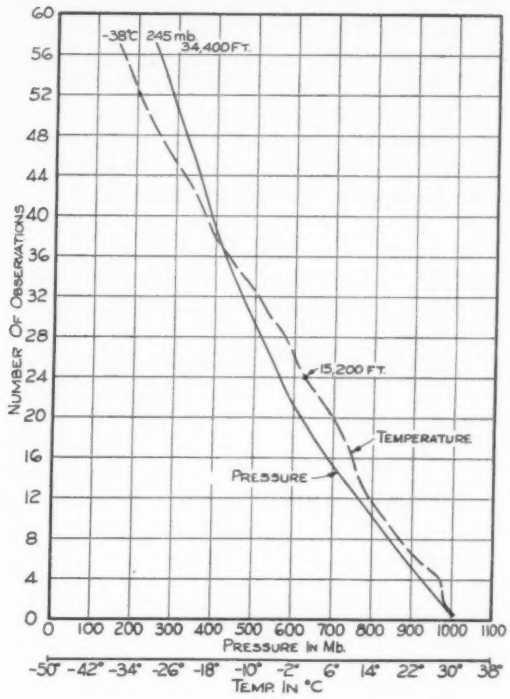

FIG. 8. Radio-meteorograph ascent record.

ASCENT RECORDS

Fig. 8 shows pressure and temperature curves obtained from a radio-meteorograph ascent. Pressure and temperature are plotted against the number of the observations, that is against time. The instrument used in this case was not equipped for humidity measurements. The balloon was inflated to ascend at a slow rate and went up about 550 ft. per min., data being recorded in a satisfactory manner for 62 minutes, at which time the watch ran down. In another case, an ascent was made with unprotected batteries in which an altitude of 46,500 ft. and a temperature of −50°C.

was recorded. In a night ascent with unprotected batteries, a temperature of −50°C. was recorded. In all flights, including the night flight, a single balloon was used to lift the instrument. For the night flight, a free lift in excess of 1100 grams was used, and an ascension rate of about 900 ft. per min. attained. The gross weight of the instrument was 423 grams.

SUMMARY

The radio has been heard 43 miles at an elevation of 8.8 miles over mountainous country. It has also been heard continuously for 70 minutes. So far there have been no failures due to the transmitter or garbling of the record due to interference. There have been no cases in which a watch has been known to stop due to low temperatures at high altitudes. Recording of meteorological data has been satisfactory for a period of over an hour and the measurement of azimuth angles accomplished. Nothing used in the construction is inherently expensive or difficult to make or obtain. The weight is less than one pound for a complete instrument. With the development of means of measuring elevation as well as azimuth angles, the instrument will enable the determination of pressure, temperature, humidity, and wind speed and direction from the surface to high altitudes.

Book Reviews

Testing of Internal Combustion Engines, by S. J. YOUNG AND R. W. J. PRYER; D. Van Nostrand Company, Inc., New York, 1937; 200 pages, ill., $3.25.

The testing of internal combustion engines is an activity in which the application of exact methods is frequently difficult and at times impossible. The more common use of higher operating speeds has measurably increased this difficulty. For this reason the development of personnel capable of obtaining reliable results and deducing accurate conclusions from them requires training of both practical and theoretical nature with emphasis placed on the many sources of error and the necessity of considering all pertinent facts in basing any decision on test data.

The authors of this book have diligently adhered to the requirements of such training. The book itself is intended for use only as general text for college or technical school laboratory work. It deals with the elementary apparatus and procedures of engine testing in a manner calculated to stimulate the interest of the student. As such it is an admirable piece of work, complete in attention to detail and thoroughly sound in theory. The only criticism which might be directed to it as a text is that it frequently devotes as much space to a minute description of a particular adaptation of one piece of test apparatus as it does to the general theory underlying its use.

It is believed that the value of this book lies solely in school use. As it deals only with the most elementary testing apparatus and instruments necessary for classroom demonstration purposes it is of no value as a guide in commercial practice to the relative values and proper uses of such equipment. Or again, dealing only with standard, conventional type low output engines manufactured several years ago it is not possible for the authors to indicate any trend in testing methods and material which might have bearing on present or immediate future work.

It is believed that this work may fill the requirements of many technical schools and colleges in this country as well as in England, and as a general laboratory text it is highly recommended.

E. M. LESTER
Pratt & Whitney Aircraft

The Air Annual of the British Empire, 1937, edited by SQUADRON-LEADER C. G. BURGE; Sir Isaac Pitman & Sons, Ltd., London, 1936; 524 pages, ill., $6.00.

To write a critical review of a book which is as well known as the Air Annual of the British Empire would indicate that readers of the Journal were not familiar with this standard reference work on British aviation. The eighth edition follows the format of previous issues with a series of informative articles on the progress in British technical developments, service aviation, civil aviation, and the industry during 1936, which is followed by well illustrated descriptions of British aircraft, aircraft engines, aircraft accessories, materials, equipment, airports and aerial survey equipment.

Nowhere else can such a comprehensive presentation of the advances made in the British Empire in 1936 be found in one volume. A list of some of the leading articles is given so that a general idea may be obtained of the contents: Centenary of the First Long-Distance Over-sea Voyage by Air, 7th November, 1936, by J. E. Hodgson; British Aircraft Developments in 1936, by S. Scott-Hall; Recent Aerodynamic Improvements in the Aeroplane, by H. B. Irving; Metallurgical Progress and the Aircraft Industry; The World Altitude Record; Empire Air-Mail Scheme for 1937; Transatlantic Air Service; Growth of the World's Air Lines; Australian Civil Aviation; Air Developments in Canada; British Record and Long-distance Flights; British Aero Engines; and Detailed Descriptions and Specifications of British Military, Commercial, and Civil Types.

The Measurement of Air Speed in Flight

F. L. THOMPSON, *National Advisory Committee for Aeronautics*

Presented at the Flying Properties and Flight Testing Session, Fifth Annual Meeting, I. Ae. S. January 29, 1937

Introduction

THE measurement of air speed of airplanes by means of instruments attached to them is often very inaccurate. The sources of error are numerous and not all of them are easily avoided. It is the purpose of this paper to discuss the results of experience gained in numerous flight tests conducted at the laboratory of the N.A.C.A. at Langley Field. Two aspects of the problem are considered, one being the measurement of air speed with a high degree of precision using special test equipment, and the other being the measurement of air speed with fair precision for normal flying. The latter aspect of the problem includes consideration of the provision of a satisfactory reference pressure for the altimeter. The use of a pitot-static head is assumed throughout.

Pitot-Static Head

The pressure prevailing at the static openings serves as a datum for the measurement of impact pressure which, for many purposes, can be considered to be equal to the dynamic pressure q or $\rho V^2/2$. It should be appreciated, however, as shown by Zahm in N.A.C.A. Report No. 247[1], that this expression neglects compressibility. The difference between the actual impact-pressure and $\rho V^2/2$ expressed as a percentage of q for sea-level conditions is shown in Fig. 1. This difference becomes 1 percent at a speed of approximately 150 m.p.h. The difference is small enough so that for convenience herein no further distinction will be made between the quantity q and the actual impact pressure.

When the pitot-static head is subjected to axial flow it usually develops the correct total pressure but seldom develops exactly the correct static pressure, owing to the effect of structural details of the head itself on the local pressure and velocity. It is possible to design a head for which the error in static pressure is small, but for very accurate work the head should be calibrated. If the pitot-static head is inclined to the airflow, there is in general a defect in both the total and static pressures. Fig. 2 shows for a typical case[2] the effect of pitch or yaw on the total pressure p_t, static pressure p_s, and the dynamic pressure q. The errors

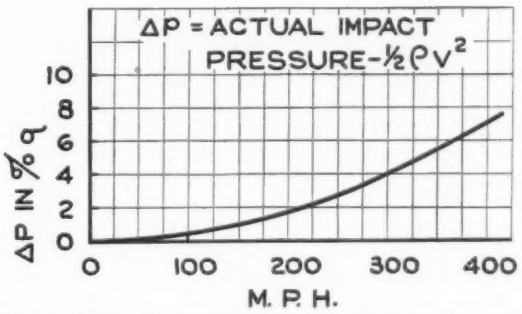

FIG. 1. Effect of compressibility of air on impact pressure.

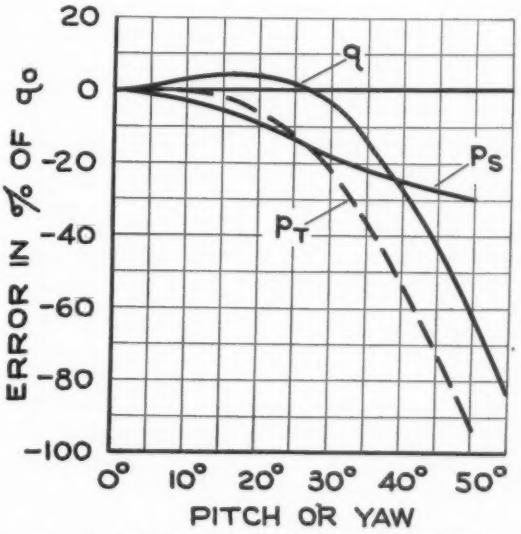

FIG. 2. Typical effect of inclination on pitot-static tube.

are expressed as a percentage of q_0, the dynamic pressure indicated by the head when set parallel to the airflow. It will be noted that the error in static pressure starts at very small angles of inclination, whereas the error in total pressure does not become appreciable until the angle has exceeded 10°.

Suspended Pitot-Static Head

Location of Head

It is generally appreciated that parts of an airplane influence the local velocity and the static pressure over a wide field. Generally speaking, these local variations in velocity and static pressure occur without alteration in the magnitude of the total pressure. This

[1] A. F. Zahm, *Pressure of Air on Coming to Rest from Various Speeds*, N.A.C.A. Report No. 247, 1926.

[2] H. Kumbruch, *Pitot-Static Tubes for Determining the Velocity of Air*, N.A.C.A. Tech. Memorandum No. 303, 1925.

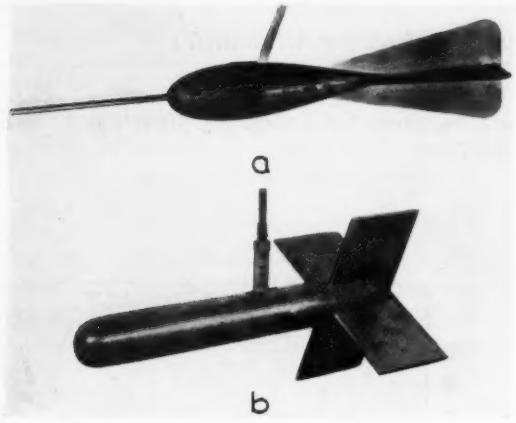

FIG. 3. Suspended air-speed heads.

statement does not apply, of course, to the propeller slipstream or the wake wherein there are losses in total head due to friction. The one convenient way of avoiding this interference is to suspend the air-speed head below the airplane on a long cable. The length of suspension required to avoid appreciable interference from the airplane depends, among other factors, on the lift coefficient and on the size of the airplane. It is necessary to take into account the fact that the head will swing backward and upward. Calculations indicate that with a suspension length equal to $1^1/_2$ span lengths on a wing with a maximum lift coefficient of 2.0, the maximum error in velocity would be less than 0.5 percent. This suspension length is suggested as the minimum acceptable length for accurate work.

Type of Head

There is no standard type of suspended pitot-static head. One type that has been used a great deal by the N.A.C.A. is shown in Fig. 3a. A more recent design is shown in Fig. 3b. The latter has the advantage of being more compact and rugged than the older type. In both cases a ring of static holes rather than a slot is used for the static pressure opening, in order to avoid susceptibility to damage. If the head is too light in proportion to the drag of the cable, it will trail almost straight back at high speeds. Experience indicates that the head should weigh at least 20 lbs. when used with a cable having a diameter of about $^3/_8$ in.

Method of Suspension

A convenient method for suspending the pitot-static head is to use a small flexible cable, say $^1/_8$ in. in diameter, with a pair of rubber tubes taped to it to conduct the static and dynamic pressures. The internal diameter of the tubing should not be less than $^3/_{32}$ in., and the outside diameter should not exceed $^1/_4$ in. If the head is to be used at moderately high speeds, it is probably better to limit the tubing size to an outside diameter of $^3/_{16}$ in. so that the complete cable will not exceed $^3/_8$ in. in diameter.

Air-Speed Indicator or Pressure Gage

The pressure difference at the upper ends of the tubes in the airplane can be observed by means of a suitable pressure gage. The instrument should be checked for leaks, for the effect on its calibration of changes in temperature or attitude, and for hysteresis. It is noteworthy that the instrument will indicate a dynamic pressure for an air density corresponding to that at the level of the indicating mechanism, rather than that at the level of the suspended head. This statement is based on the assumption that the temperature of the air in the two sides of the system is equal, a justifiable assumption under the circumstances.

Lag Error Due to Change in Altitude

In many cases it will be desired to measure the air speed with the suspended head while the airplane is either gliding or climbing. In such cases there will be an equal rate of change of pressure at each opening of the air-speed head and erroneous readings will probably be obtained unless precautions are taken to eliminate unequal lag effects in the air-speed lines. In general, an inequality in the lag characteristics will exist because of a difference in volume of the two sides of the system, or a difference in the restrictions in the lines. The static side of an air-speed indicator, for example, has a very large volume compared with that in the dynamic side, and in some cases there are additional instruments connected to the static side of the air-speed head. A simple test shows whether or not the lag characteristics in the two sides of the system are equal. A small pressure is applied simultaneously at both openings of the pitot-static head, and as this pressure is released so as to vary the pressure rapidly in both sides of the system, the reading of the air-speed indicator or pressure gage is observed. If there is an appreciable deflection of the indicator, the system requires modification. The modification consists simply of adding additional volume to the gage end of the side of the system that shows the least lag.

Errors Due to Wind Gradient

Another possible source of error with the suspended head is introduced by the variation of wind velocity with altitude. It is entirely possible under normal atmospheric conditions for the wind velocity at the elevation of the airplane to be say $^1/_2$ to 1 m.p.h. different from that 50 or 100 ft. below the airplane. If such is the case, there will be an appreciable error in the air-speed measurements. In order to avoid this source of error, it is advisable to use the average readings of flights made in opposite directions at approximately the same time.

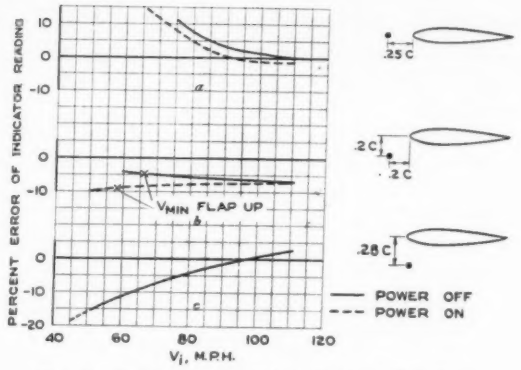

FIG. 4. Typical air-speed-installation calibrations.

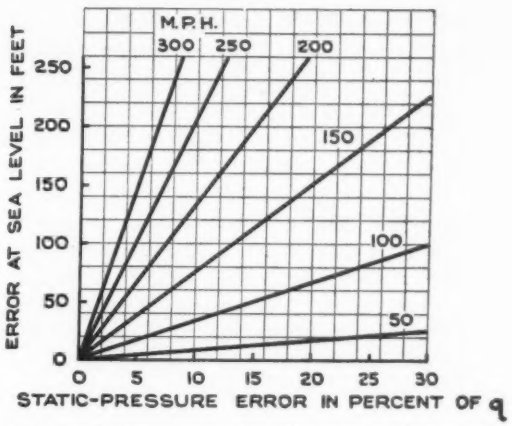

FIG. 5. Altimeter error due to incorrect static pressure.

SUSPENDED STATIC HEAD

An alternative to using the pitot-static head is to use the suspended head to obtain only a measure of the true static pressure. Since the total pressure in general is not altered by the proximity of the airplane, a measure of the correct total pressure can be obtained by means of a pitot head mounted on the airplane, provided precautions are taken to avoid errors due to inclination of the head to the direction of the airflow. Such errors can be avoided either by mounting the head on a pivot so that it is free to rotate in pitch or by using a type of head that is free from error for large angles of inclination, such as the type of head described by Kiel in N.A.C.A. Technical Memorandum No. 775.[3]

One disadvantage of this system for very accurate tests is that the air in the tube used to conduct the static pressure from the suspended head to the pressure indicating mechanism may not be at the same temperature as the surrounding air. In that case, the pressure drop due to the difference between the elevation of the suspended head and the airplane will not be the same inside the tube as outside. In general, there will not be sufficient data available on which to base a correction for this effect and a small error may result.

FIXED PITOT-STATIC HEAD

The fixed head is ordinarily subjected to angles of pitch over a considerable portion of the speed range and wing interference cannot be avoided with the fixed head to the extent that is possible with the suspended head. In fact, it will probably be necessary to accept an appreciable error at some speeds with any installation of a fixed head. In consideration of the errors incurred, it is worth noting that at the present time the problem is not only to obtain a correct value of dynamic pressure but to obtain simultaneously a source of correct static pressure for altitude reference.

[3] G. Kiel, *Total-Head Meter with Small Sensitivity to Yaw*, N.A.C.A. Tech. Memorandum No. 775, 1935.

Errors for Typical Installations

The magnitude of the error in any given case is, of course, the resultant of several effects and is often large. The errors in indicated air speed V_i for three typical cases are shown in Fig. 4. The upper plot (a) is typical for a low-wing monoplane, the head being located 0.25 c. forward of the wing, as indicated in the figure. The large difference between the curves for the power-on and power-off conditions is noteworthy. The middle plot (b) applies to a high wing monoplane equipped with partial-span flaps, but as shown in the figure, the use of the flaps had no influence on the calibration. As in the previous case, the use of power had a marked effect. The bottom curve (c) shows the calibration for another high wing monoplane with the head located below and very slightly behind the leading edge of the wing. The error at minimum speed in this case was very large but the application of power had no effect.

In order to obtain an indication of the magnitude of the error in the altimeter reading that would result in the above cases if the altimeter were connected to the static side of the air-speed head, it is permissible to assume that the errors in indicated air speed correspond to equivalent errors in static pressure. The equivalent errors in static pressure expressed as a percentage of q for any given case would be approximately two times the error in indicated velocity. In other words, it may be assumed that an error of say 10 percent in indicated velocity corresponds to a static pressure error equal to about 20 percent q. In Fig. 5, the altimeter error in feet is plotted against static pressure error in percent of q for various speeds. This figure shows that an error in static pressure equal to 20 percent q at speeds between 50 and 100 m.p.h. would correspond to an altimeter error ranging from about 20 to 70 ft. The altimeter error would remain under 10 ft. if the static pressure error were 3 percent q or less.

Satisfactory Locations of Fixed Head

For flight tests at the N.A.C.A laboratory at Langley Field, a procedure that gives satisfactory results consists in mounting a head that is free to rotate in pitch and thus aline itself parallel to the direction of the relative wind, on a long boom extending one chord length forward of the wing of a monoplane or the upper wing of a biplane. It is preferable that the head should be a little below the chord line. Errors due to inclination of the flow are thus eliminated and the error due to wing interference is reduced to small magnitude except at the extreme lower end of the speed range. At minimum speed an error in indicated air speed of 2 to 5 per cent would be typical. This type of installation ordinarily does not entirely obviate the necessity for calibration but when the calibration is obtained, it is applicable within reasonable limits to all flight conditions, that is, climbs, glides, pull-ups, take-offs, etc.

Another installation that has often been suggested consists of a fixed head mounted a little behind and above the wing. Results of a survey around wings in the N.A.C.A. full-scale wind tunnel[4] indicated that with a plain wing such an installation would give an accuracy within 2 or 3 percent of V_t at all flight speeds. An objectionable feature was that the use of flaps introduced very large errors.

[4] John F. Parsons, *Full-Scale Wind-Tunnel Tests to Determine a Satisfactory Location for a Service Pitot-Static Tube on a Low-Wing Monoplane*, N.A.C.A. Tech. Note No. 561, 1936.

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Experiments with Automatic Flaps

RANDOLPH F. HALL, ***Cunningham-Hall Aircraft Corporation***

(Received February 8, 1937)

Summary

THIS paper describes wind-tunnel research and flight testing of a high lift wing development by the author. The wing has a longitudinal passageway with a floating vane controlled opening at the under side, and principally up moving ailerons above full span automatically operated flaps. The vane, which is usually independent of the flap, only opens to by-pass air for discharge between the aileron and flap in ordinary flight when the flap is lowered. Ailerons may be correlated to depress slightly with the flap.

The passageway increases lift, especially for small displacement angles of the flap, and improves control during slow-speed flight and when taxiing. Automatic flap operation is obtained by the application of initial force to produce moments at the flap to balance air hinge moments. Lateral control through principally upward movement of the aileron is satisfactory if system instability at high speed and large operating forces at slow speed are prevented. This is accomplished by an aileron lower paddle which aids response.

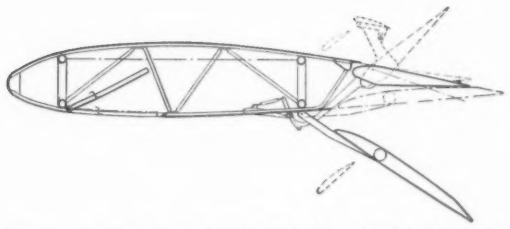

FIG. 1. Section through GA21-M wing with GA-36 aileron upper balance indicated.

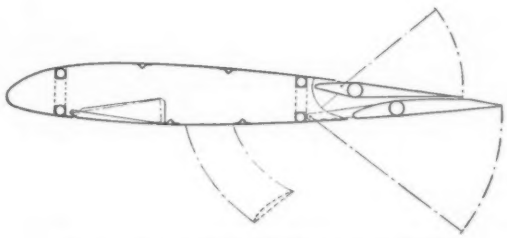

FIG. 2. Section through semi-monocoque wing.

Introduction

Owing to increased wing loadings of modern airplanes it has been necessary to rely upon high lift devices for reduction in landing speed and ground run. These devices, in the form of flaps, slots, variable area arrangements, or combination thereof, usually assist the take-off and, when most effective, improve general performance and safety. Extensive research on such devices has been in progress for some time.

The Hall wing embodies a longitudinal passageway and flaps. Wind-tunnel investigations established the basic passageway and flap arrangements. Flight data from tests of the X-90, F-22 experimental wings for the Navy, the GA21-M, and the GA-36, manufactured by the Cunningham-Hall Aircraft Corp., furnished further material for study. Flight tests have not been restricted, the action of wing elements having been observed in all attitudes of the airplane, and during maneuvers. Particular attention has been directed to lateral control for wing with full-span flaps.

Fig. 1 shows the GA21-M wing of N.A.C.A. 2415 base section, with the GA-36 aileron upper paddle balance indicated by dotted line. Air is displaced through the passageway at slow speeds when the flap is lowered. Entrance is controlled by a "front vane" which may or may not be interconnected with the rear flap. The aileron, located above the flap, is balanced by an inset hinge axis and by remote surface, the importance of which is discussed later. Ailerons are correlated to the flaps for simultaneous down movement therewith at a rate of 1:7 which increases lift and adds to the control. The hinge axis of the flap is forward its leading edge in order to provide a gap when lowered. The reduced chord flap, in comparison to one with the leading edge extended to the hinge gives better results and the structure is reduced. The floating vane may be spring loaded to delay opening, although the light springs of the GA-36 were mainly to prevent clatter on the ribs. When the flap is raised, vane being closed, profile continuity is preserved, and the wing's appearance is conventional. The vane opening provides accessibility during construction and facilitates inspection.

In the semi-monocoque stressed skin wing of Fig. 2, transverse formers are cut away for the front vane.

The GA-36 test airplane shown in Fig. 3, has tandem cockpits and non-retractable undercarriage. Test data are for 2100 lbs. weight, representing a power loading of 14.5 lbs./hp. and a surface loading of 18.1 lbs./sq. ft. The latter value is based on the actual area, but including the fuselage, the surface loading is 16 lbs./sq. ft. High speed is 155 m.p.h.

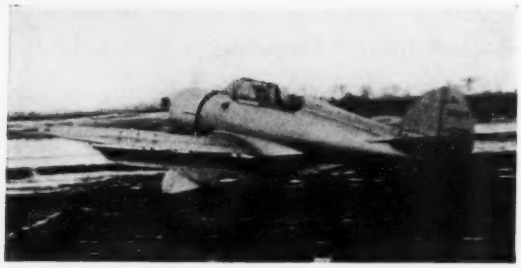

FIG. 3. GA-36 landing with flap down.

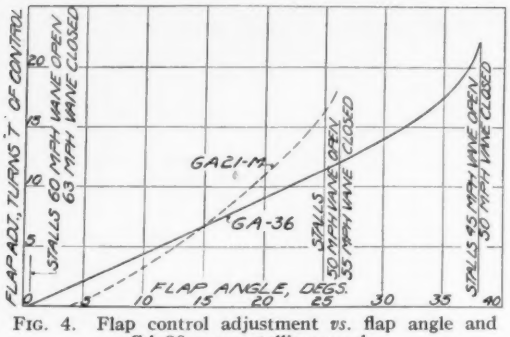

FIG. 4. Flap control adjustment *vs.* flap angle and GA-36 power stalling speeds.

THE WING PASSAGEWAY

The passageway is only open when beneficial. The floating front vane stays closed with the rear flap raised, except as noted during full stall and in certain maneuvers. When the flap lowers, a pressure difference is created, which causes the vane to open in accordance with the flap location. While 30° total vane motion was provided which was obtained in flight for flap displacements over 20°, the lift increase for the F-22 vane one-half open, indicates that less than 30° would be satisfactory.

Test Results

Air speeds are indicated values. Slow-speed values are approximately correct but high-speed readings are low. Comparative tests, passageway open and closed, followed immediately and were for the same load. In the tables, under "Flap Adjustment," the setting for extent of automatic operation is listed but the actual position of the flap depends upon the condition of flight, *e.g.*, during slow landings the adjustment is the real location and in the ordinary climb the flaps will have automatically moved upward. Maximum angular displacement of the flap in relation to the control setting is given in Fig. 4.

Stalled Flight

The GA-36 power stalling speed with flap full down 38°, with the passageway open, is some 5 m.p.h. less than with it closed, see Fig. 4. The floating vane reduces the minimum speed even with the flap raised, because the vane will open about 15 percent to permit some displacement of air near the stall. The airplanes tested, instead of falling off on a wing with considerable loss in altitude, usually just nosed down a short distance before recovering.

TABLE 1

Time and Distance of Take-Off (Frozen Cinder Runway)

Flap Adjustment	Vane Floating GA21-M Distance, Ft.	Vane Floating GA21-M Time, Secs.	Vane Fixed Closed GA21-M Distance, Ft.	Vane Fixed Closed GA21-M Time, Secs.
Up	270	7.4	275	7.6
2 T	255	7.5	265	..
8 T	248	7.8	270	..
12 T	273	8.0	..	..
18 T	285	9.0	340	10.4

TABLE 2

Landing Run Measurements (Wheel Brakes Used)

Flap Adjustment	Vane Floating GA21-M	Vane Floating GA-36	Vane Fixed Closed GA21-M	Vane Fixed Closed GA-36
Up	455	730	395	635
6 T	..	..	..	550
8 T	270	..	285	..
Down	165	160	275	192

Take-Off and Landing Runs

Time and distance of take-off, with passageway open and closed, are listed in Table 1 for different flap adjustments. Table 2 gives landing run measurements. The shortest take-off run occurs for the flap about 15°. This partial flap setting for the GA-36 best take-off was illustrated by attempts through 6 in. deep light snow with only a 700 ft. run available. The ship would barely get off in this distance with flap up; it took off readily with flap partly down; and tries with the flap full down indicated that take-off for the condition, was questionable.

Favorable ground influence for the passageway is evident. This was strikingly demonstrated when a cross wind developed during the GA21-M take-off run tests. With the floating vane, the pilot had no difficulty in keeping on the runway but with it fixed closed, the ship ran off twice and the pilot would only continue the tests with the vane floating.

Obstacle Take-Offs

Real improvement is apparent when taking off over an obstacle. Even with the flap fully raised, the floating vane is beneficial. The photograph series, Fig. 5, illustrates the GA21-M obstacle take-offs 600 ft. from the starting point. Pull-off was delayed and the air-

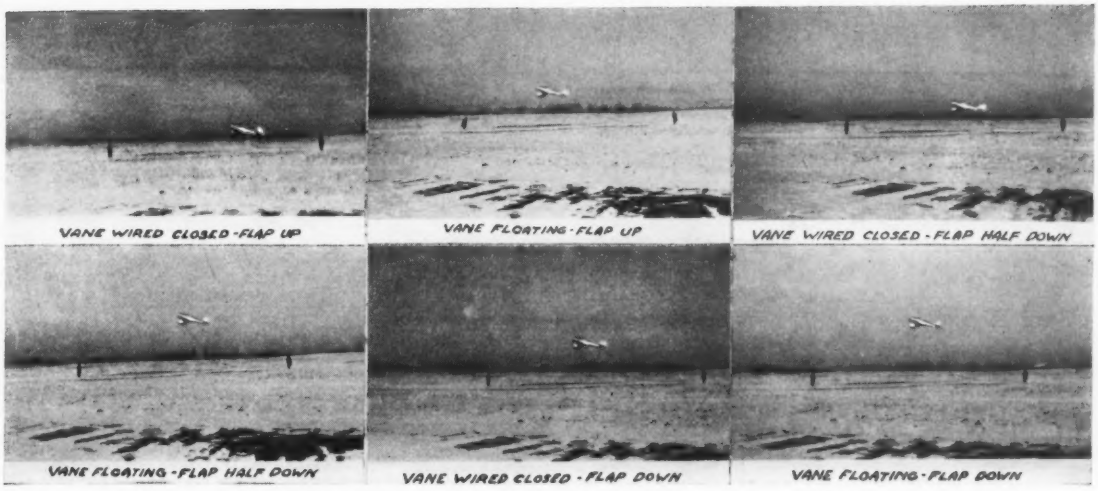
VANE WIRED CLOSED - FLAP UP
VANE FLOATING - FLAP UP
VANE WIRED CLOSED - FLAP HALF DOWN
VANE FLOATING - FLAP HALF DOWN
VANE WIRED CLOSED - FLAP DOWN
VANE FLOATING - FLAP DOWN

FIG. 5. GA21-M obstacle take-off series. Flap positions are at start of run.

plane was zoomed just before reaching the obstacle. The GA-36 tests show similar improvement, there being an increase from 18 ft. height for vane wired closed and flap up, to about 40 ft. with the vane floating and flap adjustment 8T, the obstacle being 750 ft. from the starting point.

Angle of Glide

Fig. 6 indicates that the passageway reduces the drag for small flap depression during high angle of attack but increases it for large flap angles which steepen the glide some 3°.

Airflow Experiments

To visualize the flow through the passageway, row of ribbon streamers extending rearward from within were spaced along the span. These showed a steady airflow for all positions of the flap up to the stall when turbulence became evident. Tests of the GA-36 revealed that, during ordinary flight, full raising of the flaps, causing the front vane to close, not only interrupted the outward airflow but some of the streamers went inside the wing, indicating flow reversal. A slight depression of the flap, equal to one-half turn of the control handle, made the ribbons whip out to trail instantly.

Maneuvers, Spins

During certain maneuvers with raised flap the front vane opens a little to by-pass air. Except for possibly a slight increase in the stick force laterally in tighter vertical banked turns by reason of the increased lift, this action has proven advantageous. During inverted flight the vane remains securely closed due to the negative pressure above.

No positive conclusion on the passageway effect in spins has been reached but favorable influence appears.

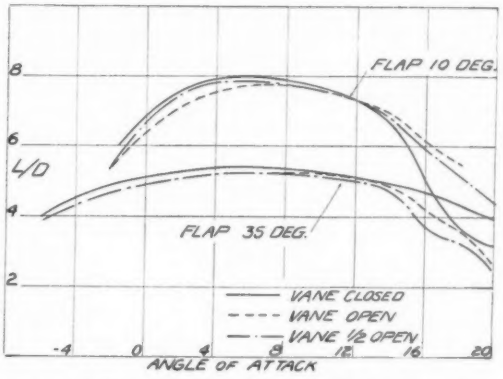

FIG. 6. L/D *vs.* angle of attack to thrust line, F-22 wing. Airplane tested in full scale tunnel without tail surfaces.

During seventy-two GA-36 test spins, changes in wing loading, center of gravity location, applied power, number and direction of turns, stabilizer setting, aileron setting, entry and recovery technique; also closing the passageway were tried with flap raised and functioning automatically. The following comment is pertinent:

For ordinary spins with raised flap, locking the front vane closed, has little influence, stick forces and recovery characteristics remaining normal.

Rigging the aileron 5° negative prevented reoccurrence of an undesirable spin tendency into which the airplane had been forced with the flap held raised on two previous occasions.

With reference to the two spins above, the airplane after a delayed recovery spin with the nose coming up for about two turns, snapped out of it abruptly after two turns with opposite control. The abruptness may have been the result of the front vane opening at the high angle of attack.

With the automatic flap in operation, spins must be forced with difficulty after spiraling several turns, and

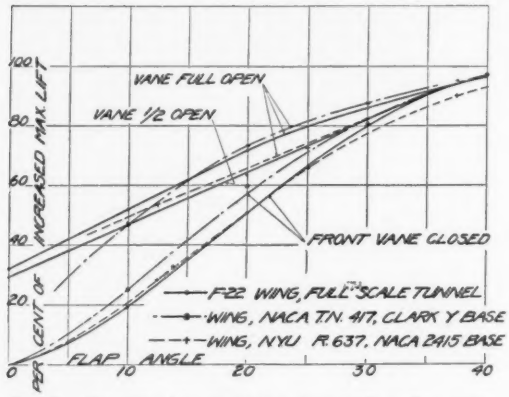

FIG. 7. Percent of increased maximum lift *vs.* flap angle.

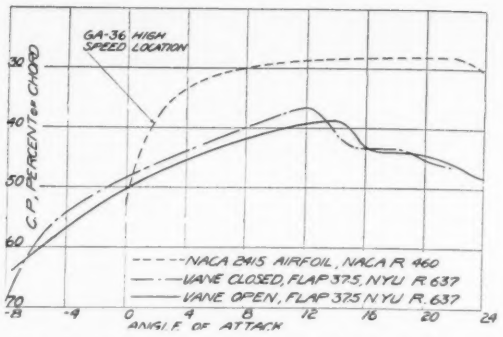

FIG. 8. Center of pressure travel showing influence of flap and passageway.

the airplane recovers instantly by releasing the controls.

Maximum Lift

In Fig. 7 the increased maximum lift is plotted against flap setting for several wings with passageway both open and closed. The significant passageway increase generally results in more lift being created with the flap depressed 10° than is obtained for the flap at 20° with the passageway closed where the drag is higher. Curves tend to coincide at large flap angles, but there is little gain in maximum lift for flap angles above 40°, which is near the ground clearance limit of low-wing craft. Flight tests indicated a maximum lift coefficient of $C_L = 2.40$ for the GA21-M and a higher value for the GA-36.

Unit weights for several wings are tabulated in Table 3. Panel weight includes ailerons, flaps, and flap controls in wing. Total weight of the automatic flap system mechanisms varied between 24 and 45 lbs.

Fig. 8 gives the center of pressure curves, passageway open and closed, flap up and 37.5° down. The center of pressure location with the flap automatically raised near high speed is about the same as it is with the flap down at slow speed.

Attempts to produce tail buffeting with the GA-36, by violently side slipping from power on or off flap down stalls, show that the airflow through the wing and above the flap leading edge avoids tail buffeting.

AUTOMATIC OPERATION

The limits of automatic movement are controllable between maximum flap depression and the locked fully raised position. The GA-36 flaps are operated by a coil compression spring initial force unit which is simpler than automatically motor driven flaps and the source of energy is permanent. A plurality of initial force units could be used for large craft. The initial force, tending to lower the flap, acts with a varying leverage which depends upon the flap location, so that

TABLE 3

Unit Wing Weights

Airplane Wing	Factor of Safety High Angle of Attack	Vane (Lbs.)	Flaps (Lbs.)	Rigging (Lbs.)	Wing Panels (Lbs.)	Wt. per Sq. Ft. Panels	Wt. per sq. ft. Panels and Rigging
F-22	7.2	8	34	64	236	1.39	1.76
GA21-M	9.5	9	36.5	27	253	2.22	2.46
GA-36	12.1	9	38.4	30	280	2.46	2.72

the applied hinge moment at the flap changes to balance the air load hinge moment, positioning the flap as required; being completely lowered at high angle of attack before stall and raised near cruising speed. Flap hinge moments may be determined from wind-tunnel coefficients provided an allowance be made for differences between tunnel tests and flight, such as for slipstream action and flap system friction.

The GA-36 system, Fig. 9, provided for direct attachment of opposite flaps to the torque tube, extending through the fuselage. The steel coil compression spring initial force unit, plus auxiliary initial force unit for experimental adjustments, attached to the centrally located crank within the fuselage, produce balanced flap operation. The spring working stress does not exceed 60,000 lbs./sq. in. as against its minimum yield stress of 120,000 lbs./sq. in. Friction is reduced by ball bearings. The initial force unit serves to lower both flap and aileron.

Instant Flap Operation

In addition to the handle for limiting the degree of flap operation, a button may be pulled to release the flap from any position for full automatic movement. The GA-36 instant release could not be operated for flap adjustment less than 4T owing to friction at the button plunger shaft, from which point, at 70 m.p.h., the flap would snap down about 5° and than lower slowly, the front vane also opening. The action is

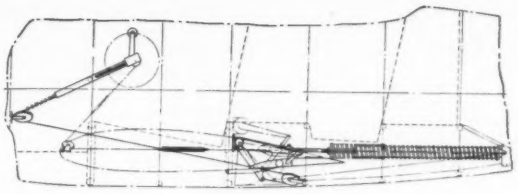

FIG. 9. Diagram of GA-36 automatic flap.

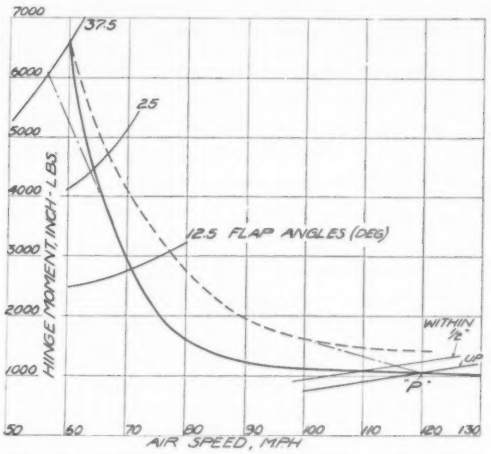

FIG. 10. GA-36 applied hinge moment *vs.* air speed.

barely felt on the stick and the flight path does not appear to change. Aside from the value of instantly placing the flap in full automatic operation in an emergency; say close to the ground or in a spin, tests so far do not show material advantage over the usual automatic operation. A hydraulic dash pot, installed in the flap system, is precautionary against flutter although it does not appear necessary except to smooth the action of the flap and serve as a safeguard against accidental tripping of the instant release control when on the ground.

Flap Hinge Moments

The GA-36 applied flap hinge moments were measured by spring scale readings at the flap with the control set for full automatic operation. Up to 25°, the moment at the flap due to leverage element changes, varies almost as a straight line, and from 25° to 38°, the rate increases. In Fig. 10, the initial force flap hinge moment is plotted, by a continuous line, against air speed. Crossing this graph are curves of the GA-36 air hinge moments for flaps raised, 12.5°, 25°, and 37.5° as determined from tunnel coefficients. Intersection of applied and air hinge moments curves locate the speeds at which the flaps automatically hold the respective flap angles.

The smooth flap motion is interesting to observe, particularly during stability tests when, for instance, with the ship trimmed for about 70 m.p.h., cutting the power and freeing the controls at stall, the airplane goes through its stabilizing oscillations, from stall to dive toward stall etc., the flaps raising and lowering.

Referring to Fig. 10, continued linear relationship of moment with flap angle would change the applied moment above 25° setting to the indicated dot-dash line. For study, it was assumed that the initial force was applied directly to a radius arm on the flap as though the torque tube through the fuselage was the flap beam with its center the axis of flap rotation. The graph of the applied hinge moment then changes to the dotted line. Such an arrangement might be satisfactory at slow speed, but unless a cam or roller mechanism modified the curve to pass near point *P*, the GA–36 flap would not raise properly at high speed. If the initial force unit attachment, see Fig. 9, is raised one hole ($^3/_8$ in.) to reduce flap-up leverage, the flap does not pass a hump unless the nose is held very high; and if, in its present attachment, the initial force is reduced some 20 lbs. by adjustment, the flap will only descend about two-thirds of its travel unless in full stalled flight. Rigging the ailerons negative was found to increase the initial force requirement. Once the proper adjustment was determined, the GA-36 flap system required no further attention. As speed is an important factor to raise the flap, the system must be designed within the power-speed limits of the airplane for the flap to close without diving. The front vane, if interconnected to the rear flap, should reduce the maximum initial force requirement some 10 to 15 percent.

Stability and Balance

Since the automatic flap raises as the speed increases, longitudinal instability encountered with fixed flaps, is not experienced with this wing. Stick force tests indicate that the position of the flap does not materially effect the longitudinal balance.

Passageway Effect on Automatic Flaps

With the passageway open, more force is required to lower the flap. This was expected by virtue of the greater lift and follows from the increase in hinge moments for flap depressed over 5° and is probably due to increased negative pressure above the lowered flap. A 17 percent maximum increase in moment for the passageway is reached when the flap is fully lowered. During inverted flight the flaps are less than one-third displaced while the front vanes stay closed.

Flight tests bear out tunnel findings that the passageway and automatic flap improve the stall condition, the slope of the lift curve becoming the envelope of the moved flap lift curves. Rearward center of pressure movement beyond the stall readjusts the flaps for speed pick up.

Advantages of Automatic Flaps

(1) The airplane may be flown with the flap set for a limited degree of automatic movement without appreciable effect upon flight characteristics for safety and the flap may be set for full automatic movement at altitude before approach for landing.

(2) Glide control is facilitated because the lift holds up for partial flap deflection, and power bursts to extend a steep glide become more effective.

(3) Short landings of either "mushing through" technique or the faster normal approach are practical, the flap being only partly down until pull-back.

(4) Acceleration during take-off, re-positioning the flap, improves the take-off performance.

(5) Automatic movement of the flap following the stall assists recovery.

(6) Longitudinal stability is maintained by the flap automatically raising at high speed.

(7) Prevention of unsafe or undesirable attitudes of the airplane by fixed flaps, or through incautious operation of manual controls.

(8) Automatic operation of the flap on the ground prevents damage, and automatic flaps on seaplanes should save damage from sea spray pounding.

(9) The operating force of manually controlled flaps is avoided.

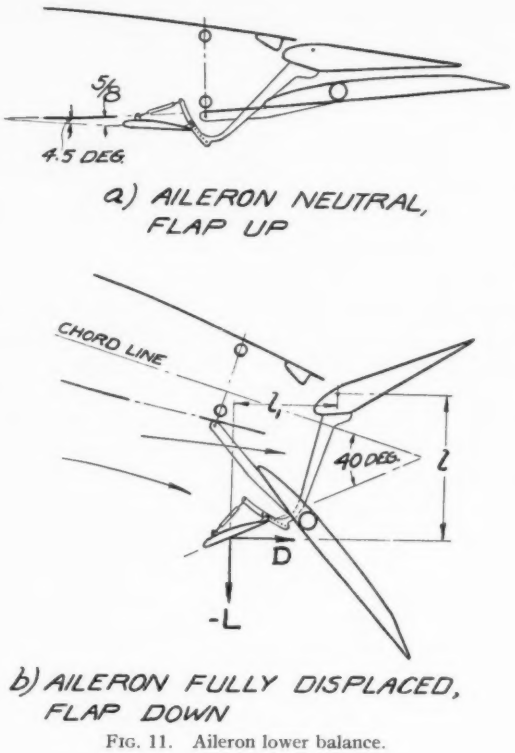

FIG. 11. Aileron lower balance.

LATERAL CONTROL

Satisfactory lateral control for flap wings is difficult. Conventional control, in itself, is inadequate at stall and becomes worse at lower speeds with flaps. Moreover, partial span flaps cannot be as effective as full span flaps. The GA-36 lateral control arrangement not only permits full span flaps, but cooperates to contribute to lift. At stall the airplane responds nicely to all controls, even with the flaps fully down. Roll maneuvers are impressive. GA-36 ailerons are rigged negative to permit 5° down movement, with an 8:1 differential which decreases to 4.4:1 when the flap is down. This provides sensitive response for small stick movements. The maximum up motion has been 45°. Balance is obtained by a 20 percent inset hinge, and by upper and lower paddles, the upper being incidental to the first job because of the inboard location of the lower paddle. The principally up-aileron control system tends to be unstable or overbalanced at a low angle of attack.

Lower Balance Paddle

The GA-36, $5^3/_4 \times 28^3/_4$ in. modified Clark Y section lower paddle, set 4.5° positive to the adjacent forward lower surface, with its leading edge $^5/_8$ in. below as in Fig. 11a, ailerons neutral and flap up, being ahead of the hinge axis, acts upward to maintain system stability. When the flap is down with the simultaneously depressed ailerons neutral, the paddle is 9.5° to the lower surface and its leading edge is just inside the wing. With full control, one paddle is about 40° negative to the wing chord or some 22° to the flight path at stall, and both the drag component, D, and negative lift, $-L$, act with considerable leverage l and l_1 to aid control movement; any decline from the peak negative lift and its leverage being compensated by the added drag factor. Drag contributes to favorable yaw while negative lift contributes to roll response in accordance with the size and span location of the balance. From Fig. 11b it would appear that flow about the lowered flap, in effect, increases the negative angle of the paddle.

Flight tests, after numerous adjustments of the lower paddles, permit the following deductions: Moving the paddle downward below the wing, within range of the adjustment provided, is detrimental to the airplane performance and seems to introduce system instability at high speed. Increasing the positive angle of the balance improves the system stability but adds to operating forces, and decreasing the angle tends to introduce system instability, for which reason it could not be set in line with the lower surface of the wing. Removing the lower paddle caused system instability at high speed for some 5-in. movement of the stick from each side of the center.

The pilot describes the feeling of instability as a sort of slight grab, like moving the controls over a cam. However, the ailerons do not flutter in any sense. Instability does not occur at slow speed. The lower paddle not only provides system stability but acts aerodynamically as a powerful balancing agency after predetermined motion of the control. Its weight serves to statically balance the control surface against flutter.

The GA-36 Upper Paddle Balance

The 4 × 48 in. St. Cyr. No. 233 Airfoil upper balance is detachably mounted near the aileron tip, $4^3/_8$ in. above the adjacent upper surface and parallel thereto with its nose just ahead of the aileron leading edge. Provision for $a = 7°$ adjustment was included. The function of this upper paddle balance was to compensate for the inboard location of the lower paddle and for experimentation as a balancing and roll producing element. With it removed, the response was found to be somewhat reduced and the stick forces slightly higher at the stall, the improvement being considered sufficient to warrant retention. A 3.5° negative setting from the design mid-adjustment was in the right direction for response and lower stick forces and did not introduce system instability, but full negative adjustment did. Fixing the balance +3.5° from its mid-location, while apparently effecting neither system stability nor response, gave higher stick forces and reduced the indicated high speed about 4 m.p.h. The final setting adopted was 2° negative from the mid-adjustment location.

Stick Force

Contrary to the conventional, the control becomes lighter at higher speeds. Properly banked turns in both directions may be made without the rudder, the nose remaining level. During the spin tests the force to hold the stick in the direction spun was much higher than when held in the opposite direction.

Tests show that a slight increase in aileron hinge movement may be expected from the passageway for high angles of attack with the flap down slightly, but the passageway reduces the moment substantially when the flap is full down, the reduction being in the order of 30 percent near high angle of attack. The passageway helps control system stability.

Letters to the Editor

June 23, 1937

Dear Sir:

Recently the first air was blown through the new wind tunnel at the University of Washington. A few minor alterations will be made before it is ready for operation under full power. It should be ready for use by the first of August, although a careful study of the quality of the air stream cannot be made until later.

The throat of this wind tunnel is rectangular, with faired corners, and it is 8 ft. high by 12 ft. wide. The maximum air speed will be approximately 250 m.p.h. It has two return passages, and, except for the test section, which has removable wooden walls with glass windows, it is constructed entirely of reinforced concrete. Two 500 hp. d.c. motors, located outside the air stream, are connected by means of shaft and bevel gears to the propellers, 14 ft. in diameter, one in each of the two return ducts. Water cooling is provided in all the vanes.

The weighing mechanism consists of a specially designed six component balance which resembles the Zahm Balance to a slight extent, but which is very rigid, and measures moments directly about the intersection of the pitch and yaw axes of rotation, located in the model nearly twelve inches above the mechanism. The model can be rotated about either, or both, of these axes, at any desired speed, by means of hydraulic cylinders supplied with oil under high pressure, and controlled by adjustable feed valves.

Measurements of force, moment, and air speed are obtained from electric meters which indicate the current flowing in seven electric weighing units. These might be called Automatic Kelvin Balances, because they automatically supply just enough current to balance the aerodynamic forces. Range changing switches are provided, making it possible to measure forces as small as 1/100 percent of maximum. All meters are mounted on a panel together with pitch and yaw indicators, clock, thermometer, barometer, and a small blackboard, on which the title of the test can be marked. The whole panel will be photographed directly on photostat paper, thus providing a permanent record of all test readings. The action of the weighing equipment is so rapid, that transient conditions may be photographed by means of a moving picture camera.

FRED S. EASTMAN
University of Washington

July 1, 1937

Dear Sir:

In the April, 1937 issue of the Journal, Mr. R. S. Hatcher presented a paper on "Rational Shear Analysis of Box Girders," and observed, in a footnote, that the assumption that $S = dM/dx$ made in my paper* represented a common type of error. He noted, further, that as a result of this error I omitted the important effect of shear in horizontal webs on shear center location and general stress distribution. This shear becomes indeed negligible in a properly designed multispar wing, where the spar flanges are loaded up by its adjacent shear carrying members rather than by shear members of other spars via outside skin. It will, however, not become negligible in many types of box girders with only two shear webs, for which my formulas were not intended to be used. The main purpose of my work was to show the paramount effect of taper, which hitherto has been neglected entirely.

It seems, therefore, that each method has its own field of application and that it little befits either of us to cast aspersions on the other. It is probable that current interest in the types of structure to which these methods apply will lead to the development of procedures more satisfactory than either of these. In the meantime, may not both be regarded as contributions to a developing art rather than as examples of "error" and "perfection?"

FELIX NAGEL

* Felix Nagel, *A Method of Figuring Shear and Torsion in Multispar Wings*, Journal of the Aeronautical Sciences, Vol. 4, No. 1, November, 1936, pages 8-9.

Institute Notes

Honors

T. P. Wright, Director of Engineering of the Curtiss-Wright Corporation, received the Honorary Degree of Doctor of Science from Knox College, Galesburg, Illinois. Juan T. Trippe, President of Pan American Airways, received an Honorary Degree of Master of Arts from Yale University.

Lecture by Soviet Trans-Polar Record Flyers

The Soviet Trans-Polar pilots, who established the world's long distance record, gave a lecture in the Engineering Auditorium in New York on July 29. The meeting was held under the auspices of the Institute of the Aeronautical Sciences in cooperation with The Aeronautical Chamber of Commerce of America, The American Geographical Society, The American Society of Mechanical Engineers, The Explorers Club, and The National Aeronautic Association.

Before the lecture, there were addresses of welcome by Major Lester D. Gardner, who acted as Chairman; and by Vilhjalmur Stefansson, President of the Explorers Club; Major General O. Westover, Chief, U. S. Army Air Corps; Dr. W. R. Gregg, Chief, U. S. Weather Bureau; Charles F. Horner, President of the National Aeronautic Association; and Major James H. Doolittle.

Constantin Oumansky, Charge d'Affaires, U. S. S. R. Embassy, introduced the Soviet pilots. Mikhail Gromoff, Chief Pilot, was ill, and his lecture was read by Andrei Yumosheff, Co-Pilot, after which he gave technical details of the flight. Sergei Danilin, Navigator, described the problems of navigation.

The lecture was broadcast in the United States and sent by short wave to Moscow, where disc recordings were made. The lecture will be reproduced in many parts of the Soviet Union.

Before the lecture, the Curtiss-Wright Corporation gave a reception for the Soviet guests after which they were honored by a small dinner party attended by Institute members and guests.

Book Reviews

Fluid Mechanics, by Russell A. Dodge and Milton J. Thompson; McGraw-Hill Book Company, New York, 1937; 493 pages, ill., $4.00.

Applied Fluid Mechanics, by Morrough P. O'Brien and George H. Hickox; McGraw-Hill Book Company, New York, 1937; 360 pages, $3.50.

An Introduction to Fluid Mechanics, by Alex H. Jameson; Longmans, Green and Company, New York; 239 pages, $2.50.

The first two books mentioned above appear simultaneously in evident response to the recent trend in engineering education which stresses the teaching of fundamental physical relations governing large groups of special phenomena. Problems of hydrostatics, aerostatics, hydraulics, hydromechanics, and aerodynamics have a common foundation in the principles of fluid mechanics. The basic equilibrium and dynamical equations are the same for all fluids, if allowance is made for the different properties of the fluids.

The Dodge and Thompson book is written by a professor of mechanics and a professor of aeronautics at the University of Michigan and is designed to cover the entire field in an introductory manner. As a text, it seems to be suitable for undergraduate engineering students and is to be commended for the skill shown in presenting topics and conceptions usually reserved for graduate or specialized study.

However, this reviewer regrets the tendency shown in this text, as in many others, to over simplify the treatment. Perhaps it is necessary to encourage the student and to coax him to think. If this premise be accepted, the book is perfect. It is written clearly, the topics are made interesting by a wealth of practical applications, and the diagrams and illustrations are extremely well done. A student, with or without the guidance of a teacher, can get from this book a working knowledge of the broad field of fluid mechanics. For members of the I. Ae. S., the text is perhaps too introductory.

My quarrel with the authors in their presentation is with their omissions. For example, under aerostatics, a simple exposition of the equilibrium of a free balloon is given, but the authors do not go into the actual variation of "specific weight" with height in an adiabatic or a standard atmosphere although the necessary mechanics of the pressure and temperature gradients have been presented in a previous chapter. Furthermore, the authors omit mention of the important conception of atmospheric stability fundamental to convection in heat transfer apparatus, and in meteorology. One might object to the use of *specific weight* in statics, and a shift to *density*, in Chapter V when dynamics is introduced.

On page 80 a short cut to Bernoulli's Theorem is taken by simply writing down a statement of the conservation of mechanical energy, but this is too easy, and the authors then have to explain under what restrictions Bernoulli's Theorem can properly be stated in this form.

In developing the mechanics of lift, the authors seem to lower their level to that of the indifferent student. The student is saved from any contact with potential theory or stream function and is told about stream lines as a consequence of continuity. The pattern of stream lines about a cylinder is shown in a diagram that is stated to be "well known in the field of classical hydrodynamics." It evidently comes from higher authority. The same higher authority gives the velocity distribution round the cylinder and, with this assumed, the student is shown how to convert velocity to a pressure distribution by substitution in formulae. When the cylinder rotates, the student is told that "it is to be expected that the velocities produced in the fluid by the rotation of the cylinder will vary inversely as the distance from the center." Here we have the vortex introduced from higher authority without a hint of the mechanics that make this fact necessary from equilibrium principles. Circulation is, of course, easily defined since circulatory motion has been invented in the above statement.

The final short cut is to tell the student that "the case of a cylinder rotating in a stream of moving fluid may now be considered as a combination of the two flows previously discussed" *i.e.*, translation and rotation. This is a true enough statement

but merely an assertion of the authors (who are first-rate men in hydromechanics and know very well that there is a theorem by which two stream functions may be combined to give the stream function for the combined flow pattern). I believe that American students like this sort of thing; where the professor has done all the thinking.

When the mechanism of flow separation is discussed on page 313, the authors write down the classical expression for the stream function for the flow about a cylinder, but do not disclose to the student that this is a stream function. Perhaps the student might shy away from it. With this formula postulated, the explanation of flow separation proceeds in a straightforward manner.

A similar solicitude for the student appears in the calculation of induced drag where the student is merely told that "methods similar to those used in electricity. . . . show that the induced drag has the value" given by a formula quoted as applicable to an elliptical plan form. No references are given for the formula so introduced, perhaps because experience shows that students will not look them up. This reviewer suggests that the authority should not have been invoked in the first place, but at least a reference to the source would be no more than fair.

Viewing the text as a whole, I have nothing but praise for its clear, direct, and scholarly presentation. To omit a few stiff steps, in order to start the student on an easy path, may be a crime in my view of education, but to many another it may well be considered a virtue.

The chapter headings which summarize the contents are as follows: Properties of Fluids, Statics of Fluids, Flotation, Accelerated Liquids in Relative Equilibrium, Dynamics of Fluids, Impulse and Momentum in Fluids, Dynamic Lift and Propulsion, The Flow of Viscous Fluids, Flow of Fluids in Pipes, Flow with a Free Surface, Flow Through Orifices and Tubes, The Resistance of Immersed and Floating Bodies, Dynamics of Compressible Fluids, Thermodynamics of Compressible Viscous Fluids, Dynamic Similarity, Special Problems in Fluid Mechanics.

In the O'Brien and Hickox book we have a somewhat more restricted field covered by two hydraulics men, the former at the University of California and the other with the Tennessee Valley Authority. As might be expected, this "Applied Fluid Mechanics" is applied principally to hydraulic engineering, but in a generalized manner that is valid for any fluid.

This reviewer has no quarrel with the presentation of the stream function or of circulation, as these conceptions are not mentioned. However, on page 182 O'Brien and Hickox introduce, without any warning or preparation, von Kármán's Vortex Street in the form of an elaborate formula involving vortex velocity. What the student is to do with it is, evidently, to be impressed with the fact that, if such vortices are shed behind a body, there should be a drag. The authors carefully show that, in practice, this drag must be determined by experiments made under proper conditions of dynamical similitude.

On page 192 the authors again inject a fundamental relation without fair warning when they state: "The coefficient of induced drag is related to the coefficient of lift by the equation $C_{D_i} = C_L^2/\pi R$." From this the student is told to get profile drag by subtraction and effective angle of attack by another formula, $\alpha i = C_L / \pi R$. A student must be incurious indeed to swallow this without protest. Perhaps such a presentation will stimulate the keen student to further inquiry, and will not annoy the sleeping one.

In general, the text is immensely superior to the conventional texts which treat hydraulics as an empirical subject. It may seem ungracious to object to a few short cuts to the presentation of basic relations, but the title is *fluid mechanics* and not hydraulics. To assume a mechanical formula is not fair in a text on mechanics.

The treatment of dimensional analysis is convincingly and simply presented except that a line on page 98 may lead the student astray. There g is stated to be "the gravitational *force* per unit mass," which it is not, but in the dimensional equation which follows, g is correctly given the form of an acceleration.

The chapter headings which summarize the contents are as follows: Hydrostatics; Flow Phenomena; Frictionless Flow; Viscosity, Turbulence, and Friction; Weirs, Orifices, and Gates; Forces Exerted by Fluids; Steady Flow in Hydraulic Pipelines; Unsteady Flow in Pipelines; Flow in Open Channels; Models of Open-Channel Flow; Physical Properties of Fluids; Hydraulic Tables.

The treatment of hydraulic flow problems is more complete than in the Dodge and Thompson book, but the latter gives a more extensive treatment of thermodynamics and dynamics of compressible fluids, elements of propeller and lubrication theory and the instruments required for fluid measurements.

On the whole, the attentive reader of either book would acquire a very useful acquaintance with the modern point of view which regards the principles of fluid mechanics as a fundamental doctrine which clarifies and organizes a mass of fluid flow phenomena. The reviewer's only complaint is that both books have been made too easy to read for the ultimate good of the young engineering student.

Professor Jameson of the University of London has prepared his compact text for undergraduates, because the University has now decided that "an elementary knowledge of Fluid Mechanics shall be required of all candidates in the Part I, B.Sc.(Engineering) Examination."

The plan of the book is to deduce the principal relations of fluid mechanics as a consequence of the application of Newtonian mechanics and dimensional theory to the physical properties of ideal and real fluids. For example, Bernoulli's Equation is deduced in such a manner that its restrictions are immediately apparent. The author does not have to make unsupported assertions about its use.

The conception of flux in fluid flow leads naturally to the Stream Function to describe it, and thence comes the natural development of stream lines as lines of constant ψ, circulation as a line integral over a closed path, vorticity as the circulation per unit area, the compounding of potential functions and hence of stream line patterns, source and sink, flow past a cylinder, etc. This elementary yet fundamental treatment of the basis of all hydromechanics takes but thirteen pages.

In the two American books reviewed above, this ground work was omitted. The Jameson book proceeds to discuss the principal hydraulic problems in a concise but satisfactory manner and with a valuable collection of worked examples.

The contents include a discussion of the properties of liquids and gases, statics, convective equilibrium, floating bodies, the perfect fluid and hydrodynamical theory, laminar flow, Reynolds experiments, the method of dimensions, resistance to motion, flow in smooth and rough pipes, weirs, orifices and nozzles, open channel flow, flow measurements.

It is to be noted that the omissions are lift and drag of wings and vanes, boundary layer separation and turbulence, lubrication, flow of compressible fluids, theory of propellers, and hydraulic machinery. In general, the author has kept to his title and has made a sound introductory text, no doubt with the belief that his students will be prepared to go forward with no handicaps into more specialized courses.

It seems to this reviewer that the choice between these three excellent texts is a matter of purpose and taste. The Dodge and Thompson book covers a very wide field and gives the student some acquaintance with all of it. The student's theoretical background ought to be filled in later by some advanced course that goes back to fundamentals. The O'Brien and Hickox book gives a good start for a hydraulic engineer who may or may not ever undertake further studies in fluid mechanics. The Jameson

book gives a sound foundation in fluid mechanics to a student who who expects to pursue further work in this field. I personally prefer Professor Jameson's approach but regret that he does not carry his text farther.

J. C. HUNSAKER
Massachusetts Institute of Technology

The Analysis of Engineering Structures, by A. J. S. PIPPARD AND J. F. BAKER; Edward Arnold and Co., London; Longmans, Green and Co., New York, 1936; 554 pages, ill., $9.00

In their new book, "The Analysis of Engineering Structures," Pippard and Baker have produced a volume which every engineer interested in structural design would find a valuable addition to his reference shelf. There is hardly a branch of structural design that is not touched on in this work which covers such diverse topics as airship rings, arches, beams curved in plan, flat slabs and plates, gravity dams, influence lines, mechanical methods of analysis, reinforced concrete, rigid frame buildings, retaining walls, secondary stresses in trusses due to joint rigidity, and suspension bridges in addition to the more usual material on beams and trusses. Not only do the authors discuss the more common methods of analysis for this wide range of structures, but they also include numerous special methods of analysis that are not to be found in any other single work. Among these may be mentioned Baker and Ockleston's distribution method for solving redundant space frames, Cross's method of moment distribution, Howard's graphical method for analyzing "beam-columns," Macauley's method of writing beam deflection formulas, Pippard's methods for the " direct design" of redundant structures and for allowing for the curvature of bars in space frames, Southwell's method of tension coefficients for reducing the labor of analyzing space frames and his method of systematic relaxation of constraints for analyzing both pin-jointed and rigid-jointed frames, and many applications of strain energy to the solution of structural problems. There is hardly a structural engineer who would not be benefited by a better grasp of at least some of these methods, few of which can be found in other texts. In addition, the authors have drawn from their experience on the Steel Structures Research Committee to discuss a number of important practical problems related to design which are not adequately covered in most books on structural theory. Altogether, though the price is higher than that of most single volumes, there is enough material in its 542 pages to fully justify its cost.

Though of great value as a reference, the same cannot be said for the book as a text for the classroom, though it is offered primarily for that use. Its chief defect from the latter point of view is that the detailed methods described are too closely tied up to specific types of structure, and not enough is said about their fundamental relationships. Thus the Wilson method of computing the reactions of continuous beams is described without discussion of the fact that it is a special case of the method of direct comparison of deflections. The application of the latter method to trusses is described, but without reference to the fact that it is the fundamental method for solving all redundant structures. Even the strain energy methods of which the authors make so much use are fundamentally but special cases of the general method of comparison of deflections. The careful student might come to realize this fact, but in a textbook even the careless student should have it forcibly brought to his attention. Another weakness is that relatively too little space is given to the derivations of the fundamental methods and too much to derivations of specific formulas. This is illustrated by the space given to deflection formulas for specific types of load.

In those fields in which the writer is most interested, the book is weakest in its coverage of methods of computing deflections. For straight beams the only method given adequate coverage is that of successive integration of the curve of M/EI. Moment areas is given only a brief description, and one which fails to point out the advantages of the method when variations in section make the method of successive integration impracticable unless the integrations are carried out by graphical or semi-graphical methods. The shear area method is barely mentioned, but that is really sufficient attention to be given it in a work of this scope. The most serious weakness of the discussion of beam deflections is the complete omission of the method of elastic weights. This is by far the simplest method of handling deflection problems complicated by non-uniformity of beam section or irregular loading diagrams, in spite of the authors' disparagement of "special methods" of computing beam deflections on page 40.

Equally weak is the discussion of the deflections of truss joints. The authors first take up the special case of computing the deflection of a loaded joint when there are no other loads on the structure besides the reactions. The method used is practically that of virtual work. At the conclusion of the article on this problem they make the astounding statement that the method cannot be extended to more complex problems. If this statement is intended to apply only to the special formula derived by the authors it is correct, but if, as seems probable, it is intended to apply to the general method of virtual work it is about as far from the truth as anything could be. The method of virtual work is actually of more extensive applicability than the strain energy methods which the authors recommend, since it can be used even when the stresses exceed the elastic limit of the materials used. The authors have also neglected the elastic weight methods for computing truss deflections although they constitute the simplest analytical methods for use when the deflections of more than one or two joints are desired.

In the discussion of "beam-columns," as members subjected to combined bending and axial load may be termed, the authors follow the awkward British practice of using the Berry formulas with tables of functions with the argument expressed in degrees. English engineers who use the Berry formulas should pray for the day when some one will publish such tables with the argument expressed in natural numbers or radians. The American aeronautical engineers have equivalent formulas and corresponding tables of functions with the argument expressed in natural numbers, and the labor of computation is so much reduced by them that they would as soon revert to the Berry tables as to advocate the substitution of pounds, shillings, and pence, for our decimal coinage.

In most cases the authors have been careful to mention the names of the originators of the methods of analysis presented. It is unfortunate, therefore, that they did not recognize the priority of Ratzersdorfer in developing, by 1920, the graphical method of analyzing beam-columns that is attributed to Howard. It is true that Ratzersdorfer did not extend the method to as many types of loading as did Howard, but for the case of end moments and a uniformly distributed side load the methods are practically identical. This can be seen from a study of N.A.C.A. Technical Memorandum No. 34, "Calculation of Wing Spars," or Appendix IV of Air Service Information Circular No. 493, "The Investigation of Structural Members Under Combined Axial and Transverse Loads," by J. S. Newell. English reviewers often complain of the slow progress of ideas in crossing the Atlantic from east to west, but in this case the ocean was crossed more rapidly than the English Channel.

These complaints regarding omissions should not be allowed to stand without some neutralizing praise for two other omissions. One is that of the development of figures of merit for different materials based on dimensional theory and the assumption of geometrical similarity. The other is that of the design of tapered struts. In many books on structural theory too much space is devoted to these interesting but practically futile mathematical diversions. In the volume under consideration both of these topics are refreshingly conspicuous by their absence.

ALFRED S. NILES
Stanford University

AERONAUTICAL REVIEWS

These brief reviews of recent articles on aviation subjects are published by the Army Air Corps for the information of its officers, and are printed here each month by permission of the Chief of the Air Corps.

Aerodynamics

Let's All Do Like the Birdies Do. "Bird Flight in Relation to Aeronautical Engineering," Captain J. L. Pritchard. Brief abstract of Royal Aeronautical Society paper and editorial criticisms of the author's suggestions for changes in aircraft design. Aeroplane, May 19, 1937, page 612.

Profile Drag Measurements in the Large Wind Tunnel of the DVL. H. Doetsch. Profile drag at low lift coefficients was measured on N.A.C.A. Series 24 air-foils at Reynolds Numbers between 2.7×10^6 and 13×10^6. The results discussed include influence of profile thickness and surface roughness, as well as the effect of flap slots and corrugations on the profile drag. DVL Report. Luftfahrtforschung, April 20, 1937, pages 173–178, 12 illus.

New Ideas on Turbulence. T. Von Kármán. Turbulent friction sets the lowest limit to the drag of any airplane and is at present the greatest impediment to increased speed. To stabilize the boundary layer up to the Reynolds Number used in up-to-date airplanes (that is, beyond speeds of 300 m.p.h. and over) is hardly feasible but the author believes that boundary layer could be kept laminar by removing the excess amount of air. Abstract, Wilbur Wright Memorial Lecture before the Royal Aeronautical Society. Aeroplane, June 2, 1937, page 671, 2 illus.

Research in England. "Although the British Report has not quite the same sanely practical outlook as its American equivalent, yet a new and refreshing tendency is noticeable to conduct wind-tunnel model work in conjunction with full-scale experiments." Aeronautical Research Committee Report for the years 1935 and 1936 is reviewed and results mentioned are compared with those given in the N.A.C.A. Report. Aeroplane, Aeronautical Engg. Supp., June 9, 1937, pages 698–700.

Wind-Tunnel Balance. Wind-tunnel balance at Royal Naval College. Sensitive element of the balance is supported on a single axis that can be moved to any of six different positions relative to the model. Engineering, June 11, 1937, page 661, 3 illus.

Description of this and other equipment displayed at the Institution of Civil Engineers exhibit. Engineer, June 11, 1937, pages 672–673, 2 illus.

Aircraft Design

At High Altitude. F. W. Lanchester. (Concluding article deals with powerplants. See Part V, Engine Design and Research for abstract.) Jour. Royal Aeronautical Soc., June, 1937, pages 437–466, 27 illus., 1 table, 8 equations.

Progress of Research 1929–1937. H. Tizard. Developments in aircraft and engine design in the past eight years during which the magazine has been published. Standard reference of aerodynamic efficiency, turbulence, theory of stability, full-scale research, engine development, and predictions for the future of heavy-oil engines. General review. Also editorial on practical innovations introduced in the airplane. Aircraft Engineering, June, 1937, pages 157–158 and 147–148.

The Radiator Wing. J. Maitrot. Proposed metal wing in which strips of the covering form radiator tubes for the circulation of cooling water for the engines. Les Ailes, May 13, 1937, page 7, 1 illus.

Aircraft Engineering Research Conference. M. Watter. Airplane performance and design characteristics, aerodynamic efficiency and interference, engine cowling and cooling, aircraft engines, seaplanes, and rotorplanes. Review of research results discussed at Langley Field at the Twelfth Annual Conference of the N.A.C.A., the aircraft industry, and Government air organizations. Aero Digest, June, 1937, pages 22–23, 90–92, 3 illus.

Shorter accounts of Conference and research results demonstrated. Western Flying, June, 1937, pages 10–11, 4 illus. Science News Letter, May 29, 1937, page 339, 1 illus. U. S. Air Services, June, 1937, pages 30, 32, 38.

Design of Floats. W. Sottorf. Float design practice in Germany and abroad is reviewed, the principal form parameters, and their effect on float properties are discussed, and a standard float design is established. Investigation of model groups with varying length/width ratio and keel angle, and a test method permitting their optimum application for any desired wing type are described. The N.A.C.A. Model 35 is compared with the DVL standard float which is used on the Ha 139 flying boat of the Deutsche Lufthansa. DVL report. Luftfahrtforschung, April 20, 1937, pages 157–167, 26 illus., 2 tables.

Lest We Forget. Major A. P. de Seversky. Design and structural considerations of a combat type airplane, with reference to lessons in design taught by the world war. Principle of multiplicity of structural members, location of fuel, visibility, and location of pilot are considered. U. S. Air Services, June, 1937, pages 16–17, 35.

Variable Wing Area. H. B. Irving. Method of varying wing area by dividing the wing into two parts along a line which is not far from the center line of the profile, and by separating the two parts by a mechanism. Two portions of the wings are hinged at the tips and connected at the body to a sort of scissors arrangements. Design and results of model tests described. Aeroplane, Aeronautical Engg. Supp., May 26, 1937, pages 636–637, 5 illus.

Stress Analysis and Structures

Constructive Measures and Safety Arrangements Affecting Stresses Arising in Pulling an Airplane Out of a Dive. H. W. Kaul. Approximations under which maximum values of stresses arising on wing and horizontal tail surfaces in righting the airplane can be expressed by simple formulas. By means of these approximate formulas influence of the structural size of airplane and the decisive flight characteristics can be followed. Reduction of stresses at severe elevator operation may be obtained by the following measures: increase of static longitudinal stability, decrease of rudder incidence ratio and maximum possible elevator deflection, increase of surface load, and controlling length. Automatic safety device against overstresses is considered which limits the elevator deflection as a function of the flight impact pressure, according to a particular control curve. DVL report. Luftfahrtforschung, April 20, 1937, pages 191–195, 5 illus., 3 equations

The Strength of Frames in Monocoque Construction. C. Gurney. Loads which come on to frames from interaction with the stringers and skin. Loads due to shear, treatment of the complete ring of a monocoque section. Loads due to curvature produced by bending, and loads due to curvature of fuselage lines are considered. Flight, Aircraft Engr. Supp., May 27, 1937, pages 32–34, 9 illus., many equations.

Strength of Monocoque and Tubular Spar Wings. H. Ebner. Strength problems in monocoque and tubular spar wings and results so far obtained. Elementary stress conditions from bending and torsion, supplementary stress conditions from induced forces and cross-sectional camber, tensile strength of shell wings in bending and torsion, bearing strength of partial shells with corrugated sheet or individual stiffeners, and stress conditions and tensile strength of tubular spars. DVL report. Luftfahrtforschung, April 20, 1937, pages 179–190, 15 illus., 1 table, many equations.

Composite I—Section Beams. L. P. Dudley. The beam considered consists of a steel section securely bolted to a lower section of high-tensile aluminum alloy, and has a weight much lower than that of a plain steel beam of equal strength. Properties of composite I-section beams when subjected to bending stresses are calculated, a method of determining the equivalent elastic modulus of a bi-metallic section is shown, and stresses due to temperature variation are discussed. Aircraft Engineering, June, 1937, pages 165–166, 2 illus., 8 equations.

Metal for the Light Airplane. J. P. Eames. Stainless steel and Alclad for aircraft construction. Comparison of physical properties, weight ratio, stainless-steel and Alclad sheet for stressed-skin construction, open-type stiffener sections used with aluminum-alloy stressed skin and the closed-type used with stainless steel, and the relative merits of welding and riveting these alloys. Western Flying, May, 1937, pages 27–28, 30, 2 illus.

Monocoque Construction. I. J. Gerard. In tests described the fuselage is assumed to be a tapered circular or elliptical-sectioned tube restrained at the front end by inertia or other loads and subject to vertical and horizontal lateral offset loads due to aerodynamic loading of the tail. A circular-sectioned cylinder was used to represent this fuselage and its strength found in pure bending, in pure torsion, and in combined bending and torsion. Data obtained are then utilized in estimating the strength of an actual fuselage. System is used by the British Air Ministry. Conclusions reached for direct compression loading, or for that due to bending are given for constructions incorporating stringers formed from strip material, and for those incorporating tubular and open-section extruded stringers. Effect on strength of insertion of reinforced holes representing cockpit openings in monocoque fuselages also investigated. Jour. Royal Aeronautical Soc., June, 1937, pages 467–492, 22 illus., 8 tables, many equations.

Stress Ratios. F. R. Shanley and E. I. Ryder. Stress-ratio method for determining allowable loads under combined loading conditions is applied to cases involving elastic stability, plastic stability, and stress (or material) failures. Test data for round steel tubes under combined bending and torsion, reduced to stress-ratio form, are plotted. Particular cases of combined loading, obtaining linear margin of safety directly from the interaction curve, tube problems covering bending and compression, bending and torsion, bending and transverse shear, interaction curves for elastic buckling of rectangular panels under various conditions of loading and fixity, interaction surfaces, and other problems. Aviation, June, 1937, pages 28–29, 43, 66, 69, 70, 12 illus., 11 equations.

Aircraft Control

Airplane Directional Control in Level Flight. W. Oppelt. Behavior of the directionally-controlled airplane according to the more important piloting systems is discussed. Simplified assumptions for airplane characteristics are made, placing the problem of the automatically-controlled airplane on a simplified control basis. Long DVL report. Luftfahrtforschung, April 20, 1937, pages 270–282, 27 illus., 3 tables, 13 equations.

Aircraft

Airplanes. Photographs of the following airplanes are contained in this issue: Bloch 200, Morane-Saulnier 405 (Hispano-Suiza 12 Ycrs); Amiot 143; Loire 250 (Hispano-Suiza 14-HA); Nieuport 160 (Hispano-Suiza 12 Xcrs); Breguet-Bizerte seaplane; Fairey Battle; Handley-Page H.P. 42 bimotored bomber; Bristol Blenheim; Armstrong-Whitworth A.W. 23 troop transport; Supermarine Scapa bomber seaplane; and the Handley Page H.P. 54 Arrow night bomber. Rev. de l'Armée de l'Air, April, 1937, 17 illus.

The Brussels Show. British, Belgium, Czechoslovakian, French, German, and Dutch aircraft, engines, propellers, and instruments exhibited are reviewed and brief references are made to interesting features of the following: The Belgian Fairey Battle two-three seat bomber (1050-hp. Rolls-Royce Merlin engine, useful load 3970 lb., range 1000 miles); Renard R. 36 fighter driven by a Hispano-Suiza "moteur canon"; Renard R.35 new pressure-cabin trimotor; Renard R-31 reconnaissance two-seater (Rolls-Royce Kestrel); S.V.5 two-seater trainer (350-hp. Armstrong-Siddeley Cheetah); military version of the Caudron Typhon (two 220-hp. Renault motors driving oppositely-rotating Ratier controllables); Morane-Saulnier 405 C.1 single-seater; Arado Ar-96 general-purpose trainer (240-hp. Argus aircooled inverted 8-cylinder engine, top speed 186 m.p.h., range 500 miles); and the Gotha twin-motored monoplane (two 240-hp. Argus engines, top speed 195 m.p.h.). Aeroplane, June 2, 1937, pages 667–670, 19 illus.

Foreign Fleets of Large Flying Boats. F. Play. Notes on large flying boats being developed or tested in the United States, England, Germany, France, and Italy. Les Ailes, May 13, 1937, page 12.

At the Brussels Show. Observations on some Belgian, British, German, French, Czechoslovakian, and Dutch aircraft, engines, and instruments exhibited. New military equipment referred to includes: the Arado Ar .96 two-seater bomber-fighter trainer, C .670 military version of the Caudron Typhon, and the Renard R. 36 fighter. In some cases performance and armament are given. Flight, June 3, 1937, pages 556–558, 564, 7 illus.

CZECHOSLOVAKIA

Visit to the Zlinska Letecka Plant. H. Moraud. Two views of the Zlin XIII two-seater military trainer (140-hp. Walter Major engine, 360 km. per hour speed) accompany an account of a visit to this Czechoslovakian plant. Les Ailes, May 13, 1937, page 9, 3 illus.

With Foreign Builders. Czeschoslovakian Zlin XII tandem two-seater powered by a 45-hp. Persy II flat-four engine. Few details. Aviation, June, 1937, page 40.

FRANCE

The Four Winds. The Romano R-110 three-seater fighter (two 450-hp. inverted-vee Renaults) will be flying shortly and should do about 300 m.p.h. Brief reference. Flight, June 3, 1937, page 549.

Mediterranean Prototype. Liore et Olivier H. 246, an improved version of the LeO H.242, has a metal hull, high wing of wood, and four Hispano-Suiza 12 Xirs 710-hp. engines in pairs, carries 26 passengers at a cruising speed of 160 m.p.h., and has a range just under 1000 miles. Brief reference. Flight, June 10, 1937, page 582.

New Airplanes in Test. Brief notes on the following military airplanes being tested: First issue—Potez 63 No. 01 triplace attack and light defence plane (two Hispano 14-Ab 670-hp. engines, 460 km./hour estimated maximum speed); Bloch 150 single-seater low-wing pursuit (Gnôme Rhône K14 880-hp. engine); Bloch 131 No. 2 bomber (two Gnôme Rhône K-14 engines), and the Caudron Renault C-670 bimotored reprisal plane designed for U. S. S. R. (Also notes on the Farman 1002 stratosphere airplane, Amiot 341 mail plane, and Breguet 470-T Fulgur and photograph of the LeO-47 flying boat having four Hispano-Suiza engines giving 1880 hp.).

Second issue: Morane-Saulnier 405 No. 2 single-seater pursuit (Hispano-Suiza "moteur canon"), and Loire 70 trimotor ocean reconnaissance flying boat. Third issue: Ramano R-110 triplace pursuit (two Renault 450-hp. engines, estimated maximum speed 480 km./hour, range 1300 km.). Les Ailes, May 13, 20, and 27, 1937, pages 11, 7, 7, 1 illus.

Potez 63. M. Lenoir. Due to its range and armament, the Potez 63 is said to be an airplane capable of warding off enemy bombers. Suggested improvements include: changing the airplane to a two-seater, increasing the visibility, arming it with a cannon to the rear, shielding the gunner's cockpit, and equipping the airplane with grenades. Les Ailes, May 20, 1937, page 13.

GERMANY

Arado, Ar 68 Pursuit Airplane. A. Frachet. German biplane is equipped with a B.M.W. VI 750-hp. engine, is armed with two heavy machine guns, and carries six bombs of 10 kg. Its maximum speed near the ground is 330 km. per hour. Information collected in Spain indicates that maneuverability characteristics of the Arado Ar 68 and also of the Heinkel He 51 pursuit are very much inferior to those of modern combat airplanes in regard to the rate of climb and landing speed. Description, characteristics, and performance of the Arado Ar 68. Les Ailes, May 20, 1937, page 6 2 illus., 2 tables.

At the Brussels Show. Arado Ar 96 new German two-seater military trainer (240-hp. inverted-vee Argus) is for instruction in flying, radio, gunnery, photography, and bombing. Photograph only. Flight, June 10, 1937, page 578d, 1 illus.

Menascos Abroad. Menasco C4S supercharged 4-cylinder inverted inline engine has been adopted for the Focke-Wulf, FW-44J light training biplane built for export. Brief reference. Aviation, June, 1937, page 37.

Photograph of nose of airplane. Western Flying, May, 1937, page 42, 1 illus.

The Youngest Junkers. Ju.90 four-motored high-speed transport monoplane will accommodate 40 passengers in five compartments. Principle of the Junkers double-wing flaps and ailerons, previously found successful, has been extended also to the double rudders. All-up weight will be 20 tons (44,800 lb.) and speed should be between 218 and 236 m.p.h. 800-hp. engines are specified. Brief note. Aeroplane, June 9, 1937, page 700, 1 illus.

GREAT BRITAIN

Backwards or Forwards? Walker Wasp tail-first pusher four-seat cabin monoplane. Special wing-tip flaps on the small front wing and on the large mainplane are the only control surfaces fitted. They are said to give full control at very low speeds and with the front wing should make an autogiro landing possible. Very few details and illustrations of model only. Aeroplane, June 9, 1937, page 710, 3 illus.

British Ensign. Armstrong-Whitworth 40-passenger 4-engined landplane for Imperial Airways has an estimated top-speed of 200 m.p.h. European class airplane has a capacity for 40 passengers, while the Empire class airplane has seats for 27 or berths for 20. Both are powered by four medium supercharged Armstrong-Siddeley Tiger IX engines, each developing 880 hp. at the take-off. Design described in detail. Aviation, June, 1937, pages 32–33, 8 illus.

The Harrow's Turret. Handley-Page Harrow's turret, illustrated in the previous issue, is of Handley-Page design although the driving mechanism is by Nash and Thompson. Brief reference. Flight, June 10, 1937, page 588.

With Foreign Builders. Bristol Blenheim medium bomber said to be the fastest machine of its type in the world. It is powered by Mercury VIII engines delivering 825 hp. at 13,000 ft. with a maximum of 840 hp. at 14,000 ft. Few details. Aviation, June, 1937, page 40.

Designed for Production. Structure of the Handley-Page Harrow heavy bomber, methods of production and assembly, and the detail design which made these methods possible. Long description. Flight, May 20, 1937, pages 494–497, 13 illus.

Empire Air Day, 1937. Some hitherto unpublished facts about British Service airplanes and equipment, impressions gleaned from flying in military airplanes during rehearsals, and reports of typical displays. Facts are given regarding equipment of the Hawker Hectors (powered by 24-cylinder Napier Dagger H-shaped aircooled engine), the Nash and Thompson gun turrets, and the Bristol Blenheim medium bombers, "by far the fastest bombers in service anywhere in the world." The Nash and Thompson gun turret and the turret on a Harrow, and some of the other airplanes are illustrated. Brief editorial on armament of British aircraft also given. Flight, June 3, 1937, pages 544–549 and 543, 12 illus.

Foreign News in Brief—Great Britain. Experiments are in progress with a liquid-cooled engine specially designed for stratosphere flights. This engine will be installed in a counterpart of the Bristol monoplane which set an altitude record of 49,944 ft. last September. Since then the plane has been flown many times to 40,000 ft. and attained a level above 50,000 ft. Later in the year it will be joined by a second machine for a prolonged series of tests of aircooled and liquid-cooled engines in the stratosphere. Brief reference. Aero Digest, June, 1937, page 83.

The Lee-Richards Annular Monoplane, 1910–1914. Unusual design of an early monoplane with annular wing form. The airplane was said to be practically free from danger of stalling, and the wing form to be such that it had no burble point. Experimental flights made by E. C. Gordon England and improvements resulting from them as described. Engineer, June 4, 1937, page 647, 2 illus.

Miles "Hawk" Primary Trainer as Used by Royal Air Force Cadets. Low-wing cantilever monoplane powered by a D. H. Gipsy Major 130-hp. engine and having a top speed of 145 m.p.h. Short description. Aero Digest, June, 1937, page 58, 3 illus.

Moss Bros. in the Air. Two-seat tandem monoplane. Few details. Aeroplane, May 19, 1937, page 616, 4 illus.

New Ideas at Heath Row. Displays at the Royal Aeronautical Society's Garden Party. Comparison of the Fairey P4/34 monoplane with the Battle, and comments on some of the other airplanes, accessories, and instruments exhibited. Aeroplane, May 19, 1937, pages 613–615, 8 illus.

Tipsy Two-Seater. Tipsy side-by-side two-seater which does 124 m.p.h. on a 50 hp. four-cylinder inline inverted Walter Mikron engine. Aeroplane, May 19, 1937, page 624, 6 illus.

Viceless Speed. Martlesham's report on the first of the Percival Men Gulls to be fitted with a Gipsy Six Series II engine and a variable-pitch propeller. Trials with three loadings, and performance. Flight, Aircraft Engr. Supp., May 27, 1937, page 34.

HOLLAND

Safety First. Scheldemusch pusher biplane having tricycle landing gear and a maximum speed of 85 m.p.h. Airplane is to be made in England. Design and performance. Flight, May 20, 1937, pages 502a, 502d, 5 illus., 1 table. Aeroplane, May 19, 1937, page 621a, 5 illus.

The Koolhoven F. K. 46. Airplane designed for training in acrobatics and used by the Dutch Air Force is powered by a deHavilland Gipsy-Major 130-hp. engine and has a top speed 175 km. per hour. Photograph and few performance figures. Les Ailes, May 20, 1937, page 8, 1 illus.

ITALY

Two Speed Records for an Amphibian. Macchi-Castoldi M.C.94 amphibian with which G. Burei and E. Rossaldi made two amphibian speed records of 256 and 248 km./hour over 1000 and 2000 km., respectively. Amphibian is designed for transport of 12 passengers and is equipped with two Wright Cyclone 750-hp. engines. Brief note. Les Ailes, May 13, 1937, pages 3–4, 1 illus.

Fiat A.P.R.-2 Commercial Airplane. A. Frachet. Italian airplane designed for transporting eight passengers over 2000 km. at a cruising speed of 350 km./hour. Two F at A.59-R 700-hp. engines power the airplane. Long description, characteristics, and performance. Les Ailes, May 27, 1937, page 6, 2 illus.

The Four Winds. The triple-engined Cant. Z.506 twin-float seaplane has been converted into a military seaplane. It has been in regular service for about a year on the Ala Littoria Mediterranean lines, and holds the world records. Brief reference. Flight, June 10, 1937, page 573.

Italian Altitude Flight to 15,655 Meters. Caproni 161 airplane (Piaggio P-XI RC-72 14-cylinder engine) with which Colonel Pezzi made a record altitude flight to 15,655 meters. Details of airplane, modified engine, and flying suit of the pilot. Les Ailes, May, 20, 1937, pages 7–8, 2 illus.

With the Foreign Builders. Ro. 37 and Ro. 37-bis two-seater long-range reconnaissance biplanes. Either the Fiat A-30 RA liquid-cooled 12-cylinder or Piaggio P. IX RC-40 9-cylinder radial is used, developing 560 hp. at 13,123 ft. Maximum speed at 9842 ft. is 201 m.p.h., and crusing range 1025 miles. Few details, specifications, and performance. Aviation, June, 1937, pages 40–41.

Italy's Height Record. Caproni 161 open-cockpit biplane in which Lt. Col. Mario Pezzi established a new world's height record of 51,348 ft. Biplane was powered by a Piaggio XI R.C. 72 14-cylinder double-row radial in which the compression ratio was increased so that the theoretical power at ground level was more than 1800 hp. References only to airplane, engine and pilot's suit and helmet. Flight, May 20, 1937, page 502, 1 illus. Aeroplane, May 19, 1937, page 660.

JAPAN

Manchuria Air Navigation Company has superintended the construction of a new wood-metal low-wing 5-passenger monoplane for use on its airline routes. The airplane is powered by a 480-hp. Nakijima Kotubvi 9-cylinder radial. Test flights indicate a maximum speed of 185 m.p.h. Brief reference. Aero Digest, June, 1937, page 84.

The Rising Sun. Ishikawajima Shipbuilding Company is preparing to manufacture radial aircooled engines and the Hitachi and Miigata Diesel firms will take up similar lines. The Aeronautical Research Institute of Japan has nearly completed a machine to fly around the world in three "hops," meaning that it will have an endurance of 80 hours without landing or refueling. A few details of this low-wing monoplane which is powered with a special liquid-cooled vee-twelve engine also developed by the Institute. Flight, June 3, 1937, page 552a, 3 illus.

U. S. A.

A 72-Passenger Job. New Boeing Clippers on order by Pan American Airways will be powered by new 1500-hp. Wright engines. Few details of layout of passenger and other compartments. Western Flying, May, 1937, page 36.

Barkley-Grow Bi-Motor. New 8-passenger transport powered by two Wasp Juniors and designed for top speed of 224 m.p.h. at 5000 ft. Very few details. Western Flying, May, 1937, page 36, 1 illus.

Boeings Latest. "... the big bomber numbered XB-15, which, we believe, has been a hugh-hush affair for years under the pseudonym 'Project A.' It has four 1000-hp. Pratt and Whitney Twin Wasps, but was designed to have four 2000-hp. motors of another make, which have not yet come up to power. . . . The American claim that the big Boeing is the first military machine to have living accommodation aboard is certainly not true." Comments on the XB-15 and the YB-17 bombers, from a British point of view. Aeroplane, June 9, 1937, page 688, 2 illus.

Now XB-15 bomber is described as the largest weight-lifting airplane flying today and as capable of outperforming the YB-17 with the exception of speed. Very brief references only to engine, living facilities, and generator voltage. Western Flying, May, 1937, page 44, 1 illus.

Boeing XB-15 for the Air Corps, tail wheel tested in drop jig, hammer shop, newspot-welding machine, two men inside and engine nacelle, and doorway in the nacelle. Photographs only. Aviation, June, 1937, pages 30–31, 7 illus.

Cessna C-37. New Airplane being used extensively for aerial photography in powered with Series 50 Warner Super-Scarab 145-hp. engine and has a top speed of 162 m.p.h. Few details. Aviation, June, 1937, page 37, 1 illus.

Honeycomb Metal Wing Features New-Eight-Passenger Airplane. W. F. Sherman. New multi-spar cellular-type stressed-skin wing developed by Barkley-Grow Aircraft Corporation and tested by the Navy Department. Long description of wing and fuselage structure and methods of producing them. Airplane is powered by two supercharged 450-hp. Wasp Jr. engines and has a top speed of 224 m.p.h. at 5000 ft. Brief reference to other parts of plane and to the fact that General Aviation Corporation of Denmark plans to manufacture it in Europe. Iron Age, July 1, 1937, pages 22–25, 7 illus.

Lockheed for Stratosphere. "Long a secret project for the Army Air Corps, this sealed-cabin Lockheed, powered with two twin-row Wasp engines, will be ready for delivery in June." Photograph only. Aviation, June, 1937, page 54, 1 illus.

Brief reference to "mysterious substratopshere plane." Western Flying, May, 1937, page 42.

Newest Bellanca. Bellanca 17–20 five-place low-wing monoplane with stressed-skin monocoque metal fuselage. Brief reference. Aviation, June, 1937, page 54.

Styles from the States. Boeing YB-17 and XB-15 bombers, and the Seversky P-35, said to do well over 300 m.p.h. and to be the fastest American pursuit airplane. Photographs and a few comments, Flight June 10, 1937, page 577, 4 illus.

Vultee two-place attack and bombardment airplane powered with a Wright Cyclone 750-hp. engine. Photograph only. Les Ailes, May 13, 1937, page 8, 1 illus.

Stinson Aircraft Corporation has announced a new SR-9FD Reliant to be powered by a 450-hp. engine. Few details only. Western Flying, May, 1937, page 44.

U. S. S. R.

A New Summer Resort. Five aeroplanes—four four-engined A.N.T. 6s and one twin-engined A.N.T. 7—make up the Soviet expedition to the North Pole from Prince Rudolf Island. Brief reference. Aeroplane, June 2, 1937, page 656.

With the Foreign Builders. ANT-35 10-seater and ZIG-1 12-seater transport airplanes. Both are powered by Soviet engines, the former by two M-85 radial aircooled 850-hp. engines, and the latter by two M-17 500-hp. engines. Few details of both transports and of the Octiabrenok flying-flea type of airplane. Aviation, June, 1937, pages 41, 42, 2 illus.

The DC-4 Douglas. Four-engined 40-passenger transport with an estimated top speed of 237 m.p.h. and cruising range of 2200 miles. Few details. Aero Digest, June, 1937, page 52, 2 illus.

Give 'er the Gun. F. Miller. Construction of the Stearman-Hammond Model Y, its control system, and methods employed in producing it. Western Flying, June, 1937, pages 12–13, 36, 38, 3 illus.

New Boeing Four-Engined Transports. Model 307 four-engined landplane and the Model 314 four-engined flying boat. The Model 307 will carry 32 passengers, a crew of four and 3700 lb. of mail and express. It is capable of a speed of 250 m.p.h. An high-altitude version for operating in the substratosphere is referred to. The Model 314 flying boat will accommodate 72 passengers, over 5000 lb. of mail and express, and will have a cruising speed around 200 m.p.h., and a range of almost 5000 miles. Details of planes to be built for Pan American and TWA. Aero Digest, June, 1937, pages 51, 52, 4 illus.

U. S. Air Services, June, 1937, page 25, 1 illus.

Aircraft Carriers

H.M.S. Ark Royal. New British aircraft carrier with accommodations for 72 aircraft. Brief references to arrester gear, crash net, and elevator. Aeroplane, May 26, 1937, page 538.

Airships

Air and Water. New Soviet dirigible, DP-9, which is rapidly nearing completion will use helium, according to reports, the gas being obtained from deposits found in various parts of the country. Engineer, May 28, 1937, page 623.

The Future of the Airship. F. W. Lanchester. Problem of long-distance flight and question of whether the solution lies in the use of airship or airplane. Reference is made to the Hindenburg disaster. Engineering, May 28, 1937, pages 613–614.

On the Wreck of the Hindenburg. C. G. Grey. Possible causes of the wreck, and criticism of the United States for past restrictions on the use of helium by foreign airships. Aeroplane, May 19, 1937, pages 602–606, 5 illus.

The Loss of the Hindenburg. A static discharge is considered as the principal cause of the disaster, according to Dr. Eckener, and a contributory cause was leakage of hydrogen in a gas cell towards the rear part of the airship. Brief note. Aeroplane, June 2, 1937, page 656.

Editorial quoting Dr. Eckener and commenting on the fact that work on the L.Z. 130 airship is being rushed. Engineer, June 11, 1937, page 665.

Air Transportation

Safety for Transatlantic Airlines. M. Lenoir. Number of floating bases necessary for a transatlantic airline computed. Aircraft used should be able to float for six hours. Les Ailes, May 13, 1937, page 8.

Pioneering in Ocean Air Transport. Preparations made by Pan American for operations on the Pacific, and the weather forecasting service, methods of navigation, scientific method of cruising control, and preparation of flight crews making these operations a success. Aero Digest, June, 1937, pages 18–21, 89, 90, 9 illus.

Russia Surveys Polar Route. Soviet base established near the North Pole to collect Moscow-United States airline data. Brief reference. Western Flying, June, 1937, page 22.

Editorial Comment. U. S. Air Services, June, 1937, pages 9–10.

Propellers

Development and Production of a Solid Steel Propeller. A. Klemin. Disadvantages of the hollow steel propeller, and principles and development of the McCauley solid steel propeller. Special airfoil of the McCauley propeller, aerodynamic efficiency, weight considerations, vibration and whirl tests, blade manufacture, detachable and adjustable blades, maintenance, inspection, and repair. Reference is made to the use of these propellers on 1936 and 1937 Air Corps' primary training planes, and to a Wright Field engineering memorandum regarding straightening blades. Aero Digest, June, 1937, pages 32, 35, 93, 94, 6 illus., 2 tables.

Electrically-Controlled Variable-Pitch Propellers. Principle of electrical control for variable-pitch propellers, and circuit diagram for propeller with automatic interrupters. Abstract from La Technique Moderne. Automotive Industries, May 22, 1937, page 773, 1 illus.

A Fully Feathering Airscrew. In a detailed description of the Curtiss-Wright propeller a statement is made that large number of these propellers are in military service use, installations including the Army Air Corps' Consolidated PB-2A two-seat pursuits and Martin B-10B bombers and the Navy's twin-engine Consolidated patrol boats. Flight, Aircraft Engr. Supp., May 27, 1937, pages 29–31, 6 illus.

New Offset Propeller. Maynard-Di Cesare propeller blades of which carry a decided arc and are offset at the hub. Few details. Western Flying, June, 1937, page 34, 1 illus.

Dousing Decibels. Large variable-pitch-propeller test tunnel lately designed for Armstrong Siddeley is of acoustical construction, embodying "splitter" panels. A remarkable silencing effect is said to be achieved by the division of the tunnel into several smaller tunnels without interfering with the free air passage through the structure. The tunnel is claimed to be the "largest silencer in the world" and, although the intensity level may be as high as 120 decibels, it is said to be possible to converse in normal tones at either end. Brief reference. Flight, June 10, 1937, page 578d, 1 illus.

More About the Single-blade Airscrew. Further information about the American Everel single-blade propeller giving design and operation details which were obtained from the Everel Propeller Corporation. Aeroplane, June 9, 1937, page 701, 4 illus.

A New British Airscrew Company. Rotal Airscrews, Ltd., which has been formed by Rolls-Royce and Bristol Aeroplane Company, will concentrate on the production of two types of constant-speed propellers, one hydraulic in operation (Hele-Shaw-Beacham) and the other operated electrically (Curtiss). The propellers will have blades of magnesium alloy but development work will also be carried out on blades made of wood or other material. Brief note. Aeroplane, June 9, 1937, page 700. Flight, June 10, 1937, page 579.

Technical Notes. In certain cases of oblique attack it is said that the wing offers a propulsive resultant. M. Budig has designed a propeller which is composed of two blades laterally disposed on one side and the other of the body and propelled by an alternating motion of rotation. Few details of propulsion for a boat and its successful study in France. Les Ailes, May 13, 1937, page 7.

An Electric V.P. Airscrew. R. E. Palmer. Long detailed description of Curtiss constant-speed full-feathering propeller with electric and manual control. Brief reference to installation on U. S. Army Air Corps and Navy air-planes. Aircraft Engineering, June, 1937, pages 159–161, 7 illus., 1 table.

Design and operation described. Western Flying, May, 1937, pages 38, 41, 1 illus.

Propellers for High-Speed Airplanes. F. Weinig. High engine horsepower required for further increase of airplane speeds should be converted as far as possible into propeller output. Possibilities of increasing propeller output by increasing the propeller diameter, blade number and width, and blade speed are considered. Limitations to maximum propeller speed near the speed of sound, necessity of decreasing propeller blade speed with increase of flight speeds, aerodynamic behavior of propellers of high-performance factors, and suitability of arrangements of propellers operating in opposite directions are discussed. DVL report. Luftfahrtforschung, April 20, 1937, pages 168–172, 12 illus, many equations.

Aircraft Instruments

Behavior of the Sperry Horizon in Steady Curvilinear Flight. E. Schmid. In order to explain the indicating error of the Sperry horizon, a theoretical investigation is made of its behavior in steady curvilinear flight, especially the position of equilibrium. Results are diagrammatically presented. Directional curves are given for improvements, and conclusions as to the usefulness of the Sperry horizon are obtained. DVL report. Luftfahrtforschung, April 20, 1937, pages 283–292, 13 illus, 1 table, many equations.

Dynamic Balancing of Small Gyroscope Rotors. O. E. Esval and C. A. Frische. Method developed at the Sperry Gyroscope Company. Choice of method, rotor mounting, reference signal, vibration instruments, filtering, voltage balance, phonograph-type and ring-type pickups, sensitivity, and production balancing. Electrical Engineering, June, 1937, pages 729–734, 15 illus.

Fixing Positions in Air Navigation. J. M. Gardner. Device developed from a commercial Star globe which permits substellar points for stars to be fixed for any instant that observations may have been made. Locating the substellar point, use of the device as a star finder, use with the sun, and precession and aberration errors are described. Aero Digest, June 1937, page 44, 2 illus.

Preparatory Work for the Construction of Gyroscopic Horizons According to the Principle for Measurement of Relative Motion. R. Boettger. Construction of a type of apparatus, considerations required for its use for the determination of the airplane flight path, measuring accuracy for compensating for the disturbing moments, and bearing friction are dealt with. DVL report. Luftfahrtforschung, April 20, 1937, pages 266–269, 5 illus.

Some Fundamental Ideas on the Artificial Horizon for Aircraft. F. Hoppe. Desired accuracy of artificial horizons to meet future problems is discussed, and the nature of the interference accelerations in regard to time during flight are examined. Physical possibilities for the construction of an horizon and a survey of some fundamental problems for compensating the interference accelerations acting on a pendulum by means of measurement of flight movement relative to the air. DVL report. Luftfahrtforschung, April 20, 1937, pages 262–265, 4 illus.

Aeroplane Stability and the Automatic Pilot. F. W. Meredith and P. A. Cooke. Longitudinal and lateral stability of an airplane, requirements of an automatic control, description of the Smith automatic pilot which is identical to the R.A.E. Mark I control designed by the authors, and performance of the R.A.E. Mark I automatic control in airplanes. Jour. Royal Aeronautical Soc., June, 1937, pages 415–430 and (disc.), 430–436, 7 illus., 1 table.

Instruments—How They Have Multiplied. R. Isaacs. Modern aircraft and engine instruments and their development since the Lindbergh flight ten years ago. Western Flying, May, 1937, pages 20–21, 26, 2 illus.

Airport Equipment

Airport Lighting Control Panel. Westinghouse control panel providing centralized and positive control of circuits to the lighting equipment of an airport. Few details. Aero Digest, June, 1937, page 62, 1 illus. Western Flying, June, 1937, pages 25–26, 1 illus.

Miscellaneous Equipment

Finding Your Way in the Air. Lt. Comdr. P. V. H. Weems. Various types of charts and maps for air navigation and their use. Aviation, June, 1937, pages 26–27, 76, 3 illus.

Oxygen Face Tent for Pilots Advocated as Safety Measure. A. L. Barach. An "oxygen face tent" to be worn by the airplane pilots at high altitudes is suggested, and it is recommended that commercial airline companies adopt compulsory oxygen inhalation for pilots navigating at from 10,000 to 12,000 ft. or over. Changes produced by oxygen want are reviewed. Very brief abstract of report to the American Medical Association. Science News Letter, June 26, 1937, page 404.

Life Saver Seat. In anticipation of regular transatlantic air service. Imperial Airways is equipping its flying boats with seats quickly convertible into life preservers. The preservers weigh 5 lb. and are inflated with air. Photograph only. Business Week, June, 1937, page 51, 1 illus.

Parachutes

Concealed Chute. New Switlik parachute completely enclosed in chair upholstery. Few details. Aviation, June, 1937, page 44.

Photography

Pyrotechnic Photography. Equipment for taking photographs from airplanes at night, which was developed by the U. S. Army Corps and Fairchild Aviation, and is now released for sale to other governments. Sequence of operations is described. Flight, June 10, 1937, pages 578d–579, 1 illus.

Materials

German Products in Airplane and Airplane-Engine Construction. K. Schraivogel. Development of materials and new forms of construction in progress in Germany, including use of structural steels, light metals, and nonmetallic materials. DVL report. Luftfahrtforschung, April 20, 1937, pages 224–227, 7 illus.

Non-Glare Glass. Aeronautical applications of Polaroid glare-eliminating glass. Brief reference. Aero Digest, June, 1937, page 64.

Uses for Plastics. Suggestions for use of plastic materials in *aircraft construction*, including replacing metal coverings by a skin of plywood with a surface of synthetic resin. The latter could be gradually increased in thickness as experience was gained until the plywood was entirely eliminated. Brief discussion. Aeroplane, June 2, 1937, page 681.

Micro-Photographical Methods. A. Kufferath. Application of modern photo-microscopy in the testing of *airplane materials*. Various types of apparatus are compared including the Vickers camera microscope, the German Orthophot, also arranged for operation with polarized light, a shop microscope for surface testing, and one with auxiliary photographic fitting. Illustrations include: Cross-sections through duralumin plate, birch plywood glued with Tego film, and ash; surface of a rubber specimen; specimen of Eloxal film on pure aluminum base; and specimen of wire netting filter. Aircraft Engineering, June, 1937, pages 162–164, 11 illus.

Metals

New Corrosion Resistant. In the new system for processing metals under test by Lockheed and Western Air Express, the substance used is driven into the pores of the metal and seams of adjoining plates to offer a waterproof acid-proof salt-spray proof surface with a wax finish. Brief reference. Western Flying, June, 1937, page 30.

The Influence of the Mean Stress of the Cycle on the Resistance of Metals to Corrosion Fatigue. H. J. Gough and D. G. Sopwith. Tests to obtain data of direct value in *aircraft design*, as well as an understanding of the general characteristics of corrosion-fatigue. Materials tested covered a range commonly used in aircraft construction, including carbon-steel streamline wire, three noncorroding steels, duralumin, and a magnesium alloy containing 2½ percent aluminum. British Iron and Steel Institute paper. Engineering, June 11, 1937, pages 673–674, 10 illus., 4 tables, 2 equations.

Engine Design and Research

Aircraft-Engine Installation Vibration Problems. J. M. Tyler. Paper previously abstracted from preprint. (See DIGEST, December 15, 1936, page 32.) Discussion by E. V. Farrar is entitled "Stresses Importance of Dampers and Connecting-Rod Structure." S.A.E. Jour. (Trans.), June, 1937, pages 252–262, 17 illus.

Aircraft Radio Shielding Judged "Too Elaborate." Present aircraft radio shielding practice was indicted as being unnecessarily complicated and costly in one of the three papers presented at the Aircraft Radio-Shielding Session, and in two others comprehensive investigations of mica spark plugs and character of the spark discharge were reported. Discussion following these papers is given with brief reviews of the papers, two of which have previously been abstracted from preprints. (See DIGEST, May 15, pages 27 and 28.) S.A.E. Jour., June, 1937, pages 18–20.

At High Altitude. F. W. Lanchester. Aircraft powerplant in its relation to altitude. Various types of superchargers are reviewed and the supercharger is considered on the ideal basis of 100 per cent efficiency with adiabatic atmosphere. Conditions are modified for "International Standard Atmosphere," and supercharger efficiency is dealt with. Difficulties connected with the supercharger in regard to temperature, intercooling between compressor and engine, variable-pitch propeller, and surface cooling applied to both engine and intercooler are discussed. Concluded. (See DIGEST, June 15, page 4, for first part which deals with aircraft.) Jour. Royal Aeronautical Soc., June, 1937, pages 437–466, 27 illus., 1 table, 8 equations.

Compression-Ignition Engine Performance at Altitude. C. S. Moore, and J. H. Collins, Jr. Paper previously abstracted from preprint. (See DIGEST, February 1, page 39.) S.A.E. Jour. (Trans.), June, 1937, pages 263–272, 18 illus.

High Output in Aircraft Engines. R. N. DuBois and V. Cronstedt. Paper previously abstracted from preprint. (See DIGEST, February 15, page 39.) S.A.E. Jour. (Trans.), June, 1937, pages 225–231, 262, 18 illus.

Some Factors Affecting the Design of Heat Transfer Apparatus. E. W. Still. Theory is developed by which the film rates of heat flow can be obtained when only overall rates of heat transfer have been observed. A series of trials with water, ethylene glycol, oils, and air have been analyzed. Heat transfer from turbulent liquids in tubes is demonstrated, and some new data presented for streamline flow. Air flow across tube nests and over gilled surfaces is considered. A method of obtaining the gill resistance to heat flow is shown and test plant used is described. Thermal conductivity constants for aluminum, copper, steel, and other substances are given. Inst. Mechanical Engrs. Proc., 1936, pages 363–411 and (discussion), 411–435, 40 illus, 9 tables, 16 equations.

Development of Heat Resisting Materials for Airplane Powerplants. F. Bollenrath. Present status, methods for better utilization, and further development. Discussion includes data obtained in tests with tempered alloys, new heavy metal alloys, and creep of cold-rolled austenitic steels, and results of endurance tests on light metal alloys for pistons. DVL report. Luftfahrtforschung, April 20, 1937, pages 196–203, 13 illus., 9 tables.

Effect of Cylinder Size on the Structural Weight of Aircraft Engines. W.-D. Bensinger. Effect of cylinder capacity on the structural weight of all separate parts is determined from an investigation of a structural series of engines having equal horsepower and standard design but different cylinder number and size. In a summary of the particular values, engines of different horsepower are tabulated and their weight per horsepower determined. Results indicate which method of construction is to be preferred in order to obtain the lowest weight. Weight of engines differing in design from those selected for test can be determined from diagrams given. DVL report. Luftfahrtforschung, April 20, 1937, pages 228–232, 11 illus, 1 table.

Government Investigates Mica Spark Plugs. M. F. Peters, H. K. King, and J. P. Boston. Mica-insulated spark plugs for aircraft engines investigated by the Bureau of Aeronautics. Very brief outline of S.A.E. paper, and discussion by O. C. Rohde of Champion Spark Plug Company. Automotive Industries, May 22, 1937, page 777.

Reduced Maintenance of Aircraft Engine Power Plants. A. V. Willgoos. Improvement made in engines to substantiate the higher power ratings, the reduction in maintenance that these improvements have brought about, and important maintenance problems still existing. Jour. Aeronautical Sciences, May, 1937, pages 286–287.

When Lindbergh Broke Down Our Sales Resistance. G. W. Vaughan. Progress in aircraft engines in the ten years since the Lindbergh flight. General review. U. S. Air Services, June, 1937, pages 23–24.

Bearings

Development, Construction, and Operation of Light-Metal Bearings. H. Wiechell. Reasons for the use of certain light-metal bearings in aircraft engines, results obtained with aluminum-copper and aluminum-silicon alloys, and the design of bearings are discussed. The Junkers bearing testing machine is described. A.T.Z., May 22, 1937, pages 235–240, 13 illus.

Superchargers

Design of Aircraft-Engine Superchargers. W. von der Nuell. Design of superchargers for high-altitude flight. Fundamental possibilities of supercharging, the designs, characteristics and performance of various centrifugal superchargers (DVL and Junkers especially), the requirements and aspects of supercharger development, and fundamentals for supercharger calculations. DVL report. Luftfahrtforschung, April 20, 1937, pages 244–253, 24 illus., many equations.

Superchargers Driven by Means of Exhaust-Gas Turbines. K. Leist. Superchargers driven by exhaust-gas turbines are compared with those coupled to the engine, and superiority of the turbo-driven supercharger in regard to altitude performance and fuel consumption is demonstrated diagrammatically. A coefficient for comparison of exhaust-gas turbine types is specified and DVL test results are discussed. Various foreign turbo systems (Lorenz, Rateau-Potez, and Moss) are shown. Results obtained on designs of individual members as well as results of measurements on temperature curves for turbine wheels are given. DVL report. Luftfahrtforschung, April 20, 1937, pages 238–243, 14 illus.

Thermodyanamic Investigation of Exhaust-Gas Turbo Supercharging and Fundamental Tests of an Exhaust-Gas Turbine. F. A. F. Schmidt. For the control of high exhaust-gas temperatures in the turbo type of supercharging for ignition engines particular measures are required. Temperatures allowable in the turbine inlet, and means for equalizing the difference between these allowable temperatures and those of the exhaust gas were investigated. An additional performance increase of the turbine was found possible by utilizing the flow energy from the exhaust gas. Theoretical considerations regarding the combined effect of engine and turbine are verified by tests. DVL report. Luftfahrtforschung, April 20, 1937, pages 233–237, 17 illus.

Engine Testing

Engine Test Stand. Portable engine testing stand used by Northwest Air Service. Cabin contains all engine instruments necessary for a run-in and unit is moved by power drive of the engine only. Few details. Aero Digest, June, 1937, page 64, 1 illus.

Measurement of Torsional Elasticity of Crankshafts. J. Geiger. Dynamic and static methods of determining the torsional elasticity of the crankshaft. Relative advantages and points to be observed in order to obtain accurate results. Abstract, ATZ, June 10, 1936. Automotive Industries, May 22, 1937, pages 774–775.

The Art of Dynamometry. N. S. Muir. New transmission dynamometer developed by the author at the British Air Ministry primarily for measurement of engine power in flight. Very long description of its development, present design, and flight tests. Installation of the dynamometer on the Jupiter VII Wapiti aircraft is illustrated. First part of this article discusses variation of engine power with height. The apparatus has also been used in the 24-ft. wind tunnel. Concluded. Aircraft Engineering, June, 1937, pages 149–156, 31 illus., 1 table, 7 equations.

Gadgets Get Explained at Fuels and Lubricants Session. Papers on instruments recently devised for knock rating of fuels, for indicating spark advance, for automatic speed-load dynamometer control, and for studying valve gear and crankshaft vibration. Brief reviews of papers previously abstracted from preprints, and discussion following. (See DIGEST, May 15, page 31 and June 1, page 30.) S.A.E. Jour., June, 1937, pages 25–26.

Influence of Humidity on Knock Ratings. J. R. MacGregor. Procedure and apparatus developed in the Ethyl Gasoline Corporation laboratories is described by E. Bartholomew in the discussion which follows the paper. The author's findings were confirmed with this different apparatus. (See DIGEST, February 15, page 24, for abstract of preprint of paper.) S.A.E. Jour. (Trans.), June, 1937, pages 243–251, 15 illus.

Engines

Accent on the Aspirate. Parts of the Napier Dagger III and Rapier VI engines and methods of producing them. A recent 100-hour run made by the Dagger III on the dynamometer brake at maximum speed (4000 r.p.m.) and high boost is referred to. Photographs of the 200-m.p.h. Hawker Hectors fitted with Dagger III engines are included. The Rapier VIs will power the Fairey light reconnaissance biplanes, and a batch of Rapier Vs has been delivered to power the upper component of the Short-Mayo composite aircraft. Flight, June 10, 1937, pages 578a–578c, 8 illus.

Aircraft Oil Engines. Current types of heavy-oil engines for aircraft are described and illustrated, including: Bristol Phoenix, Napier, Culverin, Mercedes Benz (airship engine), Coatalen V-twelve, Junkers, and the 9-cylinder aircooled two-stroke radial aircraft Diesel developed by the Czechoslovak Arms factory. A new Junkers unit developing between 1500 to 2000 hp. at less than 1.1 lb./hp. is referred to. Possibilities of the compression-ignition engine are compared with the gasoline engine for 1000 cruising hp. Specifications are given in tables for high-speed oil engines of all types and countries. This article is preceded by three others describing Diesels for all types of road transport of all countries. Automobile Engineer, June, 1937, pp. 219–221, 10 illus, and 196–218, 222–230, 63 illus, 6 tables.

Allison 1000-Hp. Engine. Vee-type liquid-cooled engine which passed the Army Air Corps 150-hour type test. Long description and specifications. Aviation, June, 1937, page 34, 3 illus.

Hallman Aircraft Company has made an aircooled conversion of the Model A Ford engine offering a decrease in weight of between 100 and 150 lb. by use of special replacement parts. Engine develops 50 hp. at 2000 r.p.m. and dry weight is 187 lb. Brief reference. Western Flying, June, 1937, page 30, 1 illus.

Allison 1000 Hp. Chemically Cooled Model 1710 Engine. Geared 12-cylinder 60-degree V-type engine designated as the first powerplant to pass U. S. Army Air Corps 150-hour type test for engines of 1000 hp. or more. It is adaptable for high-altitude operation as it permits a practical installation of a turbo supercharger sponsored by the Air Corps. Long description of engine and reference to Wright Field tests on an engine installed in an experimental plane. Aero Digest, June, 1937, pages 50, 88, 3 illus, 1 table. Shorter descriptions. Western Flying, June, 1937, page 32, 3 illus. Automotive Industries, May 22, 1937, pages 756 and 786, 1 illus.

The Aspin Engines Takes Shape. Aspin aircooled horizontally-opposed four-cylinder 1731-c.c. aircraft engine develops 80 b.hp. at 5000 r.p.m. on a 9–10 to 1 compression ratio. Remarkable feature of the engine is the small amount of exhaust noise even with exhaust pipe removed. Few details of this unit and of tests on a 250-c.c. single-cylinder unit. Flight, May 20, 1937, page 514, 2 illus.

Buessing—N.A.G. Four-Cylinder 55-Hp. Diesel Engine. Diesel engine of precombustion-chamber type having precombustion chambers set vertically into the cylinder head over to one side so as not to interfere with the valves. Drawings only. Automotive Industries, May 22, 1937, pages 771–772, 2 illus.

Foreign News in Brief—Czechoslovakia. Approval of the Walter Super-Castor 9-cylinder aircooled engine rated at 430-hp. at 2200 r.p.m. at 5742 ft. and weighing 782 lb. Brief reference. Aero Digest, June, 1937, page 82.

The Four Winds. A 450-hp. inverted aircooled vee-twelve engine with concentric propellers and Roots supercharger has been completed by the French Regnier concern. Brief reference. Flight, May 20, 1937, page 505.

R.-R.'s Latest. Comparison recently made by Rolls Royce between the Kestrel X and the Eagle I engines, composite cooling system and performance data on the four types of Kestrels, additional information on the Merlin, and engine installation. Flight, May 20, 1937, page 501, 2 illus, 1 table.

Lycoming R-680-D. New D series engine rated at 260 hp. with a 6.5 to 1 compression ratio, and at 245 hp. with a 5.5 to 1 compression ratio. Few details of new features. Western Flying, May, 1937, page 46, 2 illus.

Radial from Germany. Bramo Sh. 14A4 seven-cylinder engine with dual ignition is available with either 5.3 or 6.0 to 1 compression ratio. Maximum power output for a weight of about 290 lb. is 160 hp. for the higher ratio and 150 for the lower. Photograph only. Flight, June 10, 1937, page 576, 1 illus.

Sklenar Double Rotary 1000-Hp. Engine. In the unusual type of engine described, nine cylinders radially arranged rotate, and the crankshaft turns at nine times the speed of the engine itself in an opposite direction. Nine and five-cylinder engines of this type have been tested in France. Les Ailes, May 27, 1937, page 7.

Technical Notes. Regnier 450-hp. 12-cylinder vee engines being produced for light pursuit airplanes have Roots volumetric superchargers, and will be used with two concentric propellers turning in opposite directions Few details. A preceding note refers to the 60, 90, 140, and 180-hp. engines also being produced. A third note states that M. Regnier is convinced that aircraft engines should have a transmission, such as automobiles have, which would replace the variable-pitch propeller. He has started studies in this direction. Les Ailes, May 13, 1937, page 6.

Thoroughness in Flight-Testing Engines. Ten aircraft—including typical modern fighters, bombers, general-purpose machines and transports—are regularly engaged as flying test beds for new Bristol engines and fly between 2000 and 3000 hours every year. Brief reference to flying endurance test. Flight, June 10, 1937, page 582.

Parts and Accessories

Beheading the Mixture. Guillotine valve. A short sleeve is cut into two or four segments which guided by slots in the cylinder head, reciprocate separately over the ports. Segments are said to weigh and cost considerably less than a corresponding poppet or sleeve valve, and to give an optimum port opening and improved cooling. Few details. Flight, June 10, 1937, page 578, 1 illus.

Cuno Oil Filter. Automatic self-cleaning type of oil filter for aircraft Few details. Aviation, June, 1937, page 44, 1 illus.

New Exhaust Ring. Engle streamline exhaust ring. Few details only. Western Flying, May, 1937, page 44.

Solved. Lodge coupling providing a butt joint between metal surfaces to maintain screening efficiency for spark plugs used with radio-screened ignition system. Photograph only. Flight, June 10, 1937, page 588, 1 illus.

Breeze Exhaust Gas Analyzer. Device utilizing thermal conductivity of the exhaust gas produced by combustion of the fuel-air mixture. Few details. Aero Digest, June, 1937, page 62, 1 illus.

Engle Streamline Exhaust Ring. New type of exhaust ring which eliminates slip joints and flexible connections. Few details. Aero Digest, June, 1937, page 64, 1 illus.

Foreign News in Brief—Czechoslovakia. By means of a small oil-cracking device on a conventional 45-hp. gasoline aircraft engine, kerosene was used as fuel on a successful 2-hour flight. The device is said to reduce mineral oil to a dry gas and to cause complete combustion without smoke or odor. Brief reference. Aero Digest, June, 1937, page 82.

Injection Pumps Are Discussed by French Engineer at S.I.A. Meeting M. Outin. Plunger-type injection pump manufactured by Précision Mécanique company in France. Delivery of pump is controlled by turning the plunger around its axis, and injection timing varies automatically with quantity setting. Description of pump and its development. Automotive Industries, June 12, 1937, pages 881–882, 888–889, 5 illus.

Low-Pressure Type Fuel Injection System. Marvel low-pressure fuel-injection system is designed for mixture control when used in conjunction with aircraft engines. Description covers injection system as developed for the Continental W-670 engine. Pumpage of fuel, leakage prevention, oscillation of the plunger which effects valving at the tip, compensation for loads, idling adjustment, and spray nozzles are dealt with in detail. Aero Digest, June, 1937, pages 46, 48, 3 illus.

The Two-Speed Supercharger in Production. "Armstrong Siddeley Motors, Ltd., believe they are the first makers in this country (England) to put a motor with a two-speed supercharger into production. The new Tiger VIII motors with this gear are going into the second batch of Armstrong Whitworth Whitleys." Few details. Aeroplane, May 26, 1937, page 637.

Fuels and Lubricants

Comparison of Octane Ratings Made by Army and C.F.R. Octane ratings by the Air Corps method and the C.F.R. motor method. Comparison made by Captain F. D. Klein and R. V. Kerley. Brief abstract. Oil & Gas Jour., June 24, 1937, page 82, 1 illus, 1 table.

Polymer and Iso-octane Motor Fuels. G. Egloff. Importance of iso-octane as aircraft fuel is referred to, the value of high-octane fuels, as discussed by D. P. Barnard, is reviewed and installations already licensed are described. Industrial & Engineering Chemistry, News Ed., June 10, 1937, pages 245–246.

Stability of Aircraft-Engine Oils and Their Tests. A. von Philippovich. Requirements of lubricants under operating conditions in aircraft engines, previous views of changes taking place in the oil, and DVL opinions and tests. Process of piston-ring sticking is considered, and reasons given for opinions on the following: oxidation and carbonization (not only carbonization in the combustion chamber); movement of oxidized oil from combustion chamber to crankcase; no simple cracking of oil occurring in the piston-ring grooves; less oil oxidation in the crankcase than in the combustion chamber; condition of the circulating oil as no indication of its tendency to cause piston-ring sticking; and volatility of oil alone as not indicative of its tendency for sticking of piston rings. The DVL oxidation method, oil testing in the engine, and the DVL-oxidation and test runs described. DVL report. Luftfahrtforschung, April 20, 1937, pages 254–261, 12 illus., 5 tables.

Aircraft Radio

Ground and Ionspheric Rays. W. Ross. Attempt to compute relative intensities of ground ray and ionspheric ray in order to estimate effective ranges within which closed loop direction-finding apparatus may be used with freedom from polarization errors. Author is with the Radio Department, National Physical Laboratory. Wireless Engr., June, 1937, pages 306–314, 14 illus., 1 table, many equations.

Low Price Radio. Two-way Learadio T30-R3 crystal-controlled 100-per-cent-modulated set of 300 watts output. Few details. Aviation, June, 1937, page 44.

New Radio Antennae Hook-Up. Through experimentation with the antenna hookup of aircraft radios, technicians at the Pacific Airmotive Corporation shops have been able to increase transmission range and reception from 75 to 200 miles. Brief reference. Western Flying, May, 1937, page 34.

United Develops New Localizer. New radio-range system providing positive radio identification of exact airport locations has been perfected by United Air Lines engineers and installed at a number of cities on its coast-to-coast system. Brief reference. Western Flying, May, 1937, page 50.

The Whitewash Beam. New fog-line at Croyden coinciding with the Lorenz blind-approach beam, providing a useful transition from instrumental to visual landing. Photograph only. Aeroplane, June 9, 1937, page 702, 1 illus.

Aero Radio Digest. Lorenz system of instrument landing recently demonstrated at Indianapolis airport, the new RCA AVR-10 and AVR-10-A light-weight receivers, Bendix radio plane for use in sales and experimental work, Submidget controls, number of radio contacts between pilot and ground stations of American Airlines during 6 months, Western Electric band pass filter, and United Air Lines special 5-frequency short-wave transmitter for relay broadcasting. Few details. Aero Digest, June, 1937, pages 66–67, 6 illus.

New Radio Aid to Navigation. Use of an electromagnetic cable on the ground to guide aircraft through some of the passes of the Rockies and Sierras suggested in a brief editorial. Aero Digest, June, 1937, page 24.

Radio Range Beacon Network of the Department of Commerce. Radio facility map. Aero Digest, June, 1937, pages 42–43, 1 illus.

United's Radio Network. H. W. Roberts. Radio system maintained by United Air Lines. Ground network, method of servicing ground stations, flying equipment and methods of servicing, ground equipment, and functions of United's radio laboratories at Chicago. Long description. Aero Digest, June, 1937, pages 38, 40, 92, 6 illus.

Aeronautical Industry and Production

Plant expansion of the Porterfield Aircraft Corporation, reorganization of the Taylorcraft Aviation Company, American aeronautical exports in February, Canadian license to manufacture Burnelli UB-14 twin-engine transports, and Thompson Products plant acquired in California. Brief notes. Aero Digest, June, 1937, pages 78–80.

Porterfield's new plant to allow three-plane per day schedule. Few details. Western Flying, June, 1937, page 30.

Proposed addition to Taylorcraft Aviation Company plant, to the Wright Aeronautical Corporation plant, increased deliveries of aircraft and engines in the United States last January, Ryan expansion of manufacturing facilities to a 30-plane per month basis, new aeronautical corporations, and January exports. Brief notes. Aero Digest, May, 1937, pages 85–86.

Production Up 67.9 Per cent. Total of 96 military aircraft was delivered in the first quarter as compared to 171 military machines in the same period last year. Brief review of production statistics. Western Flying, June 1937, page 18, 1 table.

Aircraft Sales in Wide Gains. Production for first quarter was 401 commercial aircraft, 93 military aircraft, 800 commercial engines, and 484 military engines. Brief note. Automotive Industries, May 22, 1937, page 757.

More West Coast Plants. New Plants of the Aluminum Company of America, Thompson Products, Inc., and Continental Aircraft Engine Company proposed for the West Coast in addition to expansion of existing aviation factories. Brief reference to expansion reported by the Southern California aviation industry. Aviation, June, 1937, page 49.

Orders Mount. Year's first three months show production totalling $20,500,000, an increase of 67.9 per cent over same period last year. Orders of Lockheed, proposed expansion of Taylor Aircraft plant for production of 400 Cubs a month, Wright Aeronautical Corporation expansion planned, production of Aero Engineering Corporation, and Glenn L. Martin Company expansion program. Brief references. Aviation, June, 1937, pages 54, 57.

Security in New Home. New factory of Security National Aircraft. Brief reference. Western Flying, May, 1937, page 42.

Short Spans. Factory expansion started or planned for North American Aviation, Timm Aircraft Company, and Vultee Division of Aviation Manufacturing Corporation. Brief reference. Western Flying, May, 1937, page 46.

Wright Enlarges Factory. Three additions planned for the Wright Aeronautical Corporation plant including two new test cells to accommodate engines up to 2500 hp. output and using propellers as large as 20 feet in diameter. Reduction of number types in production also briefly referred to. Western Flying, May, 1937, pages 43–44.

Foreign Industry

Aeronautical Industry and National Defense. A. de la Grange. Criticism of the supply of military equipment to the French Air Force, said to be insufficient, and comparison with German industry. A note on the German aeronautical industry, in 1936, and personnel and firms constructing airplanes and engines. Rev. de l'Armee de l'Air, April, 1937, pages 365–382, 5 illus.

Enemy Influences in the Aircraft Industry. Strikes in the British aircraft industry. Aeroplane, June 2, 1937, pages 672–673.

Catching Up. British export figures for April, 1935–1937 for airplanes, airships, balloons, and parts are compared. Brief reference. Aeroplane, June 2, 1937, page 682.

Orders and Deliveries

Report of commercial airplane deliveries for month ended May 10. Table only. Aviation, June, 1937, page 61, 1 table.

May deliveries of planes and parts set a new all-time high 42 per cent above last year. Brief reference. Business Week, June 26, 1937, page 11.

Taylorcraft Aviation Corporation announces orders for 266 airplanes received during the first 4½ months and production will be speeded up to 50 a month. Brief reference. Western Flying, May, 1937, page 44.

Menasco Manufacturing Company is shipping an engine a week to Holland to fill an order for 15. Brief reference. Western Flying, May, 1937, page 42.

Army Opens Plane Bids. Army bids for basic combat type airplanes and mono-place pursuit airplanes. Brief reference to firms competing. Western Flying, May, 1937, pages 44, 46.

Short Spans. Consolidated Aircraft Corporation has been given permission to contract for the export sale of its military version of the PBY-1. One flying boat with spares and license rights for production has been sold to the Soviet government. Brief reference.

Factory expansion of the Douglas Aircraft Company, deliveries now at the rate of $1,250,000 a month, and backlog in Army, Navy, and civilian orders (in value). Brief references. Western Flying, May, 1937, pages 36, 38.

Air Forces

Short Spans. Northrop Corporation is understood to have obtained an order for 35 attack airplanes from Argentina, and to have sold license rights to Sweden with one plane. Brief reference. Western Flying, June, 1937, page 34.

Canada

The Canadian government has placed contracts amounting to $14,000,000 for military, naval, and air equipment of which $10,000,000 will be expended in Canada and largely for air equipment. Brief reference. Iron Age, June 10, 1937, page 112.

France

A Long Parliamentary Debate on National Defense. Extracts from the debate in the Chambre des Deputes in connection with the budget for National defense, especially that part given by Pierre Cot, Air Minister, and dealing with equipment and reorganization of the Armée de l'Air. Rev. de l'Armée de l'Air, April, 1937, pages 442–451, 10 illus.

Great Britain

Air Ministry Contracts. List of orders placed by the Department during March without mention of amounts or price. Aircraft Engineering, June, 1937, page 167.

Empire Air Day. R.A.F. airplanes of 17 different types, 57 in all, gave demonstrations at civil airports, and certain units did a considerable amount of cross-country flying between service stations. Review of flight exhibitions. Aeroplane, June 2, 1937, pages 662–664, 7 illus.

Imperial Communications and Defence. Questions of Imperial Air Defence and air communications raised at the Imperial Conference in London. Brief review only. It is said that the Australian Air Force this year will complete Part I of the scheme laid down by Sir John Salmond and will have a first-line strength of eight squadrons and 96 aircraft which will later be expanded to 17 squadrons and 194 aircraft. Aeroplane, June 2, 1937, page 659.

New Squadrons. Five new bomber squadrons being formed during the first two weeks of June. Brief reference. Aeroplane, June 9, 1937, page 695.

One-Eyed Pilots. British Air Ministry's objection to granting licenses to one-eyed pilots who in other ways are 100 percent fit. Criticism. Aeroplane, June 2, 1937, page 660.

Parachute Escapes. Twenty-four lives were saved by the use of parachutes in the R.A.F. during twelve months. All Reserve pilots are equipped with parachutes for flying training. Aeroplane, June 9, 1937, page 696.

The R.A.F. Demonstration of dive bombing will be carried out at the Display at Hendon by a Fighter Squadron which is armed with Hawker Fury Mark II fighter planes. Brief reference only to this and other events. Aeroplane, June 2, 1937, page 665, 1 illus.

The Four Winds. Brief reference to four-wheeled undercarriage fitted to the new Boeing XB-15 bomber for the Army Air Corps and to a special Lockheed Electra delivered to the Air Corps for high-altitude research. Flight, May 27, 1937, page 527.

G.H.Q. Air Force Problem Ends. ". . . according to Major General Frank M. Andrews, Chief of the G.H.Q. force, although the test of the problem showed every unit involved in the campaign to be highly efficient, it also showed them to be undermanned and underequipped, and emphasized the dire need for additional airdromes." Brief account of maneuvers in California. Western Flying, June, 1937, page 22, 1 illus.

Account and editorial comment. U. S. Air Services, June, 1937, pages 11–13 and 9, 3 illus.

Reinforcements at 100 M.P.H. Non-stop flight from Calshot to Gibraltar was made by two Saro London flying boats of the R.A.F. in eleven hours to bring reinforcements to the nursing staff of the British military hospital. Brief reference. Aeroplane, June 9, 1937, page 695.

To Malta in an Aircraft Carrier. A. E. Barlow. Account of trip on the "Courageous" in the Spring Cruise of the British Home Fleet, with references to squadrons and airplanes attached to this carrier. Maneuvers of the various squadrons are described. A brief editorial note refers to previous arresting gear used by the U. S. and British Navies. To be continued. Aeroplane, June 9, 1937, pages 691–694, 15 illus.

The Waziristan Operations. Cooperation of R.A.F. airplanes with ground forces in a surprise night advance of the Bannu Brigade. A camp was supplied from the air with 10,000 lb. of supplies dropped by parachute from R.A.F. airplanes. Brief reference. Four Vickers Valentia troop carriers of No. 70 (Bomber) Squadron, flown from Iraq to India to supplement the R.A.F. units, are to be used to carry supplies up to the advanced camps and for transport of wounded. Brief reference. Aeroplane, June 2 and 9, 1937, pages 665 and 693.

Why Accidents Happen. Large number of accidents happening to R.A.F. airplanes during the last few months, comparison with the few at the British Civil Aviation schools, and with the high number in the German Air Force. General discussion, but no statistics. A second brief article deals with questions asked in the House of Commons regarding the fatal accidents to R.A.F. personnel in connection with Empire Air Day. Aeroplane, June 9, 1937, pages 690, 695.

Brief editorial on four more fatal R.A.F. crashes. Flight, June 10, 1937, page 565.

A Naval Occasion. C. M. McAlery. Review Flight by the Fleet Air Arm planned as part of the Royal Coronation. Review of the Fleet at Spithead. General account. Aeroplane, May 26, 1937, pages 640–641, 7 illus.

Italy

On Italy's Future in the Air. C. G. Grey. Italy's basic industries and how Italy's air power is being built. Italian chaser machines are said to be divided into interceptor machines capable of climbing to 8000 meters in 8 minutes, and fighting machines capable of sustained flight at speeds of over 510 km. per hour. Italy is said to possess over 10,000 pilots now. General discussion only. Aeroplane, May 26, 1937, pages 634–635, 1 illus.

Discussion by General Valle. Italian aviation situation. Parts of report to the government given by the Under Secretary of State for Aeronautics. Les Ailes, May 20, 1937, page 9.

Jugoslavia

The Four Winds. A squadron of ten Hawker Furies with multi-guns and Rolls-Royce Kestrel XVI engines has been delivered to Jugoslavia. The Jugoslavian Fury climbs to 20,000 ft. in 8 minutes and has a maximum speed of 250 m.p.h. Further Furies are to be built in Jugoslavian factories and 75 Kestrel XVIs have been ordered. Brief reference. Flight, May 27, 1937., page 527.

New Zealand

Foreign News in Brief. The New Zealand Air Force is to be augmented by three squadrons immediately, as part of an elaborate defense plan. Brief reference. Aero Digest, June, 1937, page 80.

Peru

A number of Japanese airplanes have been ordered by the Peruvian Government. Reasons for their selection include low cost. Brief reference. Les Ailes, May 13, 1937, page 10.

U. S. A.

Flashes. An Army plane, used for experiments in extinguishing forest fires from the air, was called upon to prevent a real forest fire by the use of suppression bombs, which it did successfully. Brief reference. Western Flying, June, 1937, page 22.

U. S. S. R.

New Seversky Contract. The Russian Government has purchased from the Seversky Aircraft Corporation amphibian airplanes on a contract involving more than $700,000. Brief reference. U. S. Air Services, June, 1937, page 22.